

Special Environmental Control and Life Support Equipment Test Analyses and Hardware

CR-199201

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ORIGINAL CONTAINS
COLOR ILLUSTRATIONS

Final Report

NAS8-38250

Prepared for:



Marshall Space Flight Center
Huntsville, AL 35812

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ELECTRONICS

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Contract Number NAS8-38250
Special Environmental Control and Life Support
Systems Test Analysis and Hardware
FINAL REPORT

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Acronyms

4BMS	Four Bed Molecular Sieve
ACC	Analytical Control Coordinator
BMI	Battelle Memorial Institute
CDRA	Carbon Dioxide Removal Assembly
COTR	Contracting Officer's Technical Representative
CP	Cost Plus
CPFF	Cost Plus Fixed Fee
CR	Cost Reimbursement
DTO	Detailed Test Objective
FEDS	Freedom Environmental Database System
FP	Fixed Price
G&A	General and Administrative
ION	ION Electronics, Inc.
LE	Level of Effort
LFSPE	Liquid Feed Solid Polymer Electrolyzer
LSI	Life Systems, Inc.
MCA	Major Constituent Analyzer
MINS1	Marshall Information Network System Node 1
MLS	Mostly Liquid Separator
MTU	Michigan Technological University
O/H	Overhead
OSC	Orbital Sciences Corporation
PCWQM	Process Control Water Quality Monitor
PO	Purchase Order
QA	Quality Assurance
RTI	Research Triangle Institute
SFE	Static Feed Electrolyzer
SOW	Statement Of Work
TCCS	Trace Contaminant Control System
TOCA	Total Organic Carbon Accountability
UAB	The University of Alabama at Birmingham
UAH	The University of Alabama in Huntsville
VCD	Vapor Compression Distillation
VRA	Volatile Removal Assembly
WMS	Waste Management System
WP	Water Processor

1.0 INTRODUCTION

This final report summarizes NAS8-38250 contract events, "Special Environmental Control and Life Support Systems Test Analysis and Hardware". This contract was performed for the Structures and Dynamics Laboratory, Environmental Control and Life Support Branch, Marshall Space Flight Center, Alabama. The Contract's Contracting Officer was Mr. John Cather/GP52. Mr. Cather's Representative was Mr. Michael Sosebee/GP52-B. The Contracting Officer's Technical Representative (COTR) was Ms. Mary Traweek\ED62.

This is a comprehensive contract report. The report is technical and includes programmatic development.

2.0 HISTORY

ION Electronics (ION) responded to Solicitation Number RFP-8-1-9-ED-20357 issued in the Commerce Business Daily May 17, 1989. A proposal was submitted on July 19, 1989, and notice of contract selection was received August 10, 1989. After several "fact finding" meetings contract negotiations were performed on September 27, 1989. A Notice of Contract Award was received September 29, 1989, for a cost reimbursement fixed fee type of contract, NAS8-38250 for "Special Environmental Control and Life Support Systems Test Analysis and Hardware". The award letter defined a contract commencing on October 16, 1989, and continuing for a period of 12 months in the amount of \$1,522,832. In addition to the basic effort there were two option periods of 12 months each. The options were priced as follows: Option Year 1, \$1,014,217, Option year 2, \$767,247. Initial funding was received for \$378,000 to cover cost and fee from October 16, 1989 through December 31, 1989. 40 subsequent modifications extended the contract through September 30, 1995 and raised the contract value to \$16,394,617.

The contract's Statement of Work (SOW) was outlined by Task. The initial contract Tasks and their respective titles were:

- Task A Sample Collection, Handling, and Storage
- Task B Physical, Chemical, and Microbial Assessment of Water Samples
- Task C Physical, Chemical, and Microbial Assessment of Air Samples
- Task D Physical, Chemical, and Microbial Assessment of Solid Samples
- Task E Microbial Assessments of Surfaces
- Task F Data Services
- Task G Documentation
- Task H Off-Site Laboratory Analyses
- Task I Special Test Hardware Procurement / Fabrication
- Task J Special Test Supplies Procurement
- Task K Engineering Consulting Services
- Task L Hazard Analyses and Safety Panel Support

Twenty-eight (28) "major" subcontractors were utilized to implement this contract and 1702 Purchase Orders (PO) were let for various supplies and services.

2.1 Modifications

Forty modifications were implemented on the contract. The modifications and their purpose are summarized in Table 2.1 and further described in this section. Table 2.2 summarizes contract funding while Figure 2.1 shows a time line of contract activities.

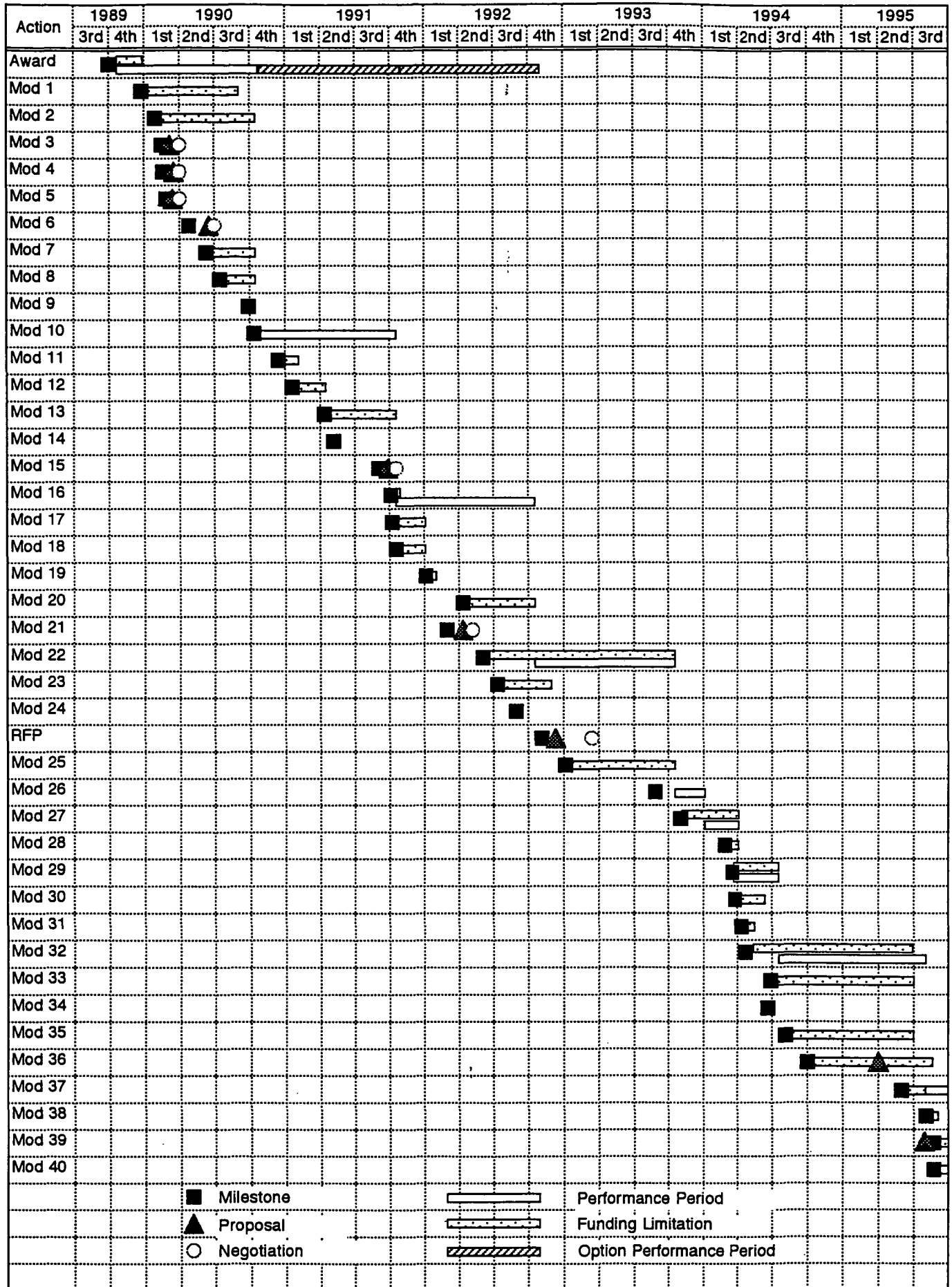
Table 2.1
Contract Modification Descriptions:

Mod. Number	Description	Performance Period
Award	Award and funding	10/15/90
1	Incremental Funding	
2	Incremental Funding	
3	Change Order, revising microbiological analyses	
4	Change Order, additional equipment	
5	Change Order, Oracle and Medical Monitor consultants	
6	Change Order, for expanded Database activities	
7	Equitable Adjustment for Change Order 5	
8	Equitable Adjustment for Change Order 3 & 4	
9	Equitable Adjustment for Change Order 6	
10	Change Order, Exercise Option 1	10/15/91
11	Incremental Funding	
12	Incremental Funding	
13	Incremental Funding	
14	Supplemental Agreement, G&A and O/H rate	
15	Change Order, "Optimization of the in-line sterilizer"	
16	Change Order, Exercise Option 2	10/15/92
17	Change Order, "Unibeds & Database" and provisional funding	
18	Equitable Adjustment for Change Order 15	
19	Equitable Adjustment for Change Order 17	
20	Incremental Funding	
21	Change Order, "Upgrading the VCD"	
22	Space Station Restructure Tasks and funding	10/15/93
23	Equitable Adjustment for Change Order 21	
24	Mutual Agreement, Organizational conflicts of interest	
25	Incremental Funding	
26	Contract Extension, "Excusable Delays"	12/31/93
27	Change Order, "PCWQM & MLS" and provisional funding	3/30/94
28	Change Order, "Process Pump" and provisional funding	
29	Change Order, Restructure RFP, and provisional funding	
30	Provisional Funding	5/31/94
31	Equitable Adjustment/funding for Change Order 27, 28, & 30	6/15/95
32	Incremental Funding	
33	Provisional Funding	
34	Government Furnished Property	
35	Change Order, Provisional Funding	
36	Equitable Adjustment for Change Order 29	
37	Change Order, "Urine Ersatz" and Provisional Funding	
38	Mutual Agreement	8/31/95
39	Change Order, "Task extension" and Provisional Funding	
40	Mutual Agreement	9/30/95

Table 2.2
Contract Modification Funding Summary

Mod. Number	Estimated Cost	Fixed Fee	Cost Plus Fixed Fee	Funding	Total Funding
Award	\$1,397,094	\$125,738	\$1,522,832	\$378,000	\$378,000
1				\$1,000,000	\$1,378,000
2				\$144,832	\$1,522,832
3					\$1,522,832
4					\$1,522,832
5					\$1,522,832
6					\$1,522,832
7	\$72,077	\$4,685	\$76,762	\$76,762	\$1,599,594
8	\$606,302	\$39,410	\$645,712	\$645,712	\$2,245,306
9	\$409,344	\$32,748	\$442,092	\$442,092	\$2,687,398
10	\$1,421,192	\$122,999	\$1,544,191	\$0	\$2,687,398
11				\$360,000	\$3,047,398
12				\$250,000	\$3,297,398
13				\$934,191	\$4,231,589
14					\$4,231,589
15					\$4,231,589
16	\$703,897	\$63,350	\$767,247	\$34,700	\$4,266,289
17	\$225,000	\$0	\$225,000	\$225,000	\$4,491,289
18	\$97,674	\$5,860	\$103,534	\$100,000	\$4,591,289
19	(\$59,300)	\$11,485	(\$47,815)	(\$47,815)	\$4,543,474
20				\$736,081	\$5,279,555
21					\$5,279,555
22	\$1,575,506	\$133,042	\$1,708,548	\$978,919	\$6,258,474
23	\$429,967	\$21,721	\$451,688	\$300,000	\$6,558,474
24					\$6,558,474
25				\$881,317	\$7,439,791
26					\$7,439,791
27	\$445,200		\$445,200	\$445,200	\$7,884,991
28	\$205,000	\$0	\$205,000	\$205,000	\$8,089,991
29					\$8,089,991
30	\$500,000	\$0	\$500,000	\$500,000	\$8,589,991
31	\$1,926,884	\$276,937	\$2,613,821	\$2,091,480	\$10,681,471
32				\$112,341	\$10,793,812
33	\$1,239,000	\$0	\$1,239,000	\$1,239,000	\$12,032,812
34					\$12,032,812
35	\$1,000,000	\$0	\$1,000,000	\$1,000,000	\$13,032,812
36	\$2,845,024	\$228,781	\$3,073,805	\$3,073,805	\$16,106,617
37	\$88,000	\$0	\$88,000	\$88,000	\$16,194,617
38					\$16,194,617
39	\$200,000	\$0	\$200,000	\$200,000	\$16,394,617
40					\$16,394,617

Figure 2.1 NAS8-38250 Time Line



A Precontract Cost Recognition was accepted by ION and NASA on October 25, 1989 in which all reasonable and allocable cost not in excess of \$10,000, incurred by ION subsequent to September 29, 1989, would be allowable to the extent such cost would be allowable if incurred subsequent to the execution of the resulting contract.

Modification (1) one was effective December 20, 1989. The modification incrementally funded the contract for an additional \$1,000,000 through August 31, 1990. Total funding was \$1,378,000.

Modification (2) two was effective January 26, 1990. The modification fully funded the contract for an additional \$144,832 through October 15, 1990. Total funding was \$1,522,832.

Modification (Change Order) (3) three, was effective February 13, 1990. The purpose of the modification was to revise the microbiological analysis requirements of the Statement of Work (SOW) by deleting references to microbial analyses in Tables 3, 4, and 5 to incorporate a new Table 5 entitled "Independent Microbiological Analyses". This new Table expanded microbial effort under Tasks B, C, and E. ION submitted a proposal on March 5, 1990 and negotiated the changed work described in the modification for the base year level of effort and both option years. Negotiations were performed on June 15, 1990 with an estimated cost and fixed fee of \$320,762 and \$20,850 respectively.

Modification (Change Order) (4) four, was effective February 16, 1990. The purpose of the modification was to incorporate a requirement under Task I of the contract for procurement of additional equipment, components, and materials in support of Environmental Control and Life Support System Phase III Test Beds as described in Table A. ION submitted a proposal on March 16, 1990 and negotiated the changed work described in the modification on June 15, 1990. Negotiations were performed on June 15, 1990 with an estimated cost and fixed fee of \$285,540 and \$18,560 respectively.

Modification (Change Order) (5) five, effective February 21, 1990, revised Task K of the Statement of Work (SOW) to incorporate a requirement for Oracle software consultant effort and interim medical monitoring support. ION submitted a proposal March 12, 1990 and negotiated the changed work described in the modification on June 15, 1990. Negotiations were performed on June 15, 1990 with an estimated cost and fee of \$72,077 and \$4,685 respectively. Subcontracts were let to Oracle Corporation and The University of Alabama in Huntsville for software consultant and medical monitor, respectively.

Modification (Change Order) (6) six revised Task F of the SOW, effective April 23, 1990, to incorporate a requirement for expanded data basing of laboratory results. ION submitted a proposal May 14, 1990 and negotiated the changed work described in the modification on June 15, 1990 for an estimated cost of \$ 409,344 and fixed fee of \$32,748.

Modification (7) seven, effective June 27, 1990, provided for an equitable contract adjustment as a result of negotiations of modification (5) five. The modification incrementally funded the contract for an additional \$76,762 through October 15, 1990. Total funding was \$1,599,594.

Modification (8) eight, effective July 13, 1990, provided for an equitable contract adjustment as a result of negotiations of modifications (3) three and (4) four. The modification incrementally funded the contract for an additional \$645,712 through October 15, 1990. Total funding was \$2,245,306. A subsequent subcontract was awarded to The University of Alabama at Birmingham for the expanded microbial analyses described in Modification No. 3.

Modification (9) nine, effective September 24, 1990, provided for an equitable contract adjustment as a result of negotiations of modification (6) six. In addition Section H was modified to incorporate an amendment for maximum Overhead (O/H) and General and Administrative (G&A) expense rates allowable under the contract, 80% and 32.7% respectively, for the base and option year 1. The modification incrementally funded the contract for an additional \$442,092 through October 15, 1990. Total funding was \$2,687,398.

Modification (Change Order) (10) ten exercised Option 1 of the contract on October 15, 1990. The performance period was extended through November 30, 1990.

Modification (11) eleven was effective December 11, 1990. The modification incrementally funded the contract for an additional \$360,000 through January 31, 1991. Total funding was \$3,047,398.

Modification (12) twelve was effective February 19, 1991. The modification incrementally funded the contract for an additional \$250,000 through April 15, 1991. Total funding was \$3,297,398.

Modification (13) thirteen was effective April 11, 1991. The modification incrementally funded the contract for an additional \$934,191 through October 15, 1991. Total funding was \$4,231,589.

Modification (14) fourteen was effective May 1, 1991. The modification incorporated an amendment to Section H setting forth a maximum G&A expense rate, 16%, allowable under the contract applicable to procurement of certain equipment through October 15, 1991.

Modification (Change Order) (15) fifteen, effective September 3, 1991, amended the SOW to incorporate a requirement for the "Optimization of the in-line sterilizer". ION submitted a proposal September 26, 1991 and negotiated the changed work described in the modification on October 11, 1991.

Modification (Change Order) (16) sixteen exercised Option 2 of the contract on September 27, 1991. The modification incrementally funded the contract for an additional \$34,700 through November 1, 1991. Total funding was \$4,266,289. The performance period was extended through October 15, 1992.

Modification (Change Order) (17) seventeen, effective October 4, 1991, incorporated a revision of the contract for an addition to Basic Task G & I of the SOW and provisionally increased the estimated cost and allocated funding pending subsequent negotiation of ION's proposal submitted November 25, 1991. The modification increased funding by \$225,000 through December 31, 1994, to yield \$4,491,289 total funding.

Modification (18) eighteen, effective October 16, 1992, provided an equitable contract adjustment as a result of negotiations of modification (6) six. The modification incrementally funded the contract for an additional \$100,000 through October 15, 1990. Total funding was \$4,591,289.

Modification (19) nineteen, effective January 6, 1992, provided an equitable contract adjustment as a result of negotiations of modification (17) seventeen. The modification also amends the key personnel section. The modification backed out \$225,000 in provisional funds and funded the negotiated amount of \$177,185 through January 31, 1992. Total funding was \$4,543,474.

Modification (20) twenty was effective April 11, 1991. The modification incrementally funded the contract for an additional \$736,081 through October 15, 1992. Total funding was \$5,279,555.

Modification (Change Order) (21) twenty-one, effective February 5, 1992, incorporated a requirement under Task H "Special Test Hardware Procurement/Fabrication" for upgrading the Vapor Compression Distillation (VCD) Urine Reclamation system. ION submitted a proposal on April 8, 1992 which was negotiated on May 26, 1992.

Modification (22) twenty-two, effective June 2, 1992, incorporated revisions to the contract for an expansion of certain tasks in the SOW. As a result of the restructure of Space Station Freedom, revised sampling requirements were necessary for verification of the Environmental Control Life Support System. Contract Modification No.22, essentially a new contract, extended the performance period through October 15, 1993 and rearranged some contract tasks. Funding was increased by \$978,919 yielding \$6,258,474 total funding.

Task A	Sample Collection, Handling, and Storage
Task B	Physical, Chemical, and Microbial Assessment of Water Samples
Task C	Physical, Chemical, and Microbial Assessment of Air Samples
Task D	Physical, Chemical, and Microbial Assessment of Solid Samples
Task E	Microbial Assessments of Surfaces
Task F	Documentation
Task G	Off-Site Laboratory Analyses
Task H	Special Test Hardware Procurement / Fabrication
Task I	Special Test Supplies Procurement
Task J	Engineering Analyses Services
Task K	Hazard Analyses and Safety Panel Support

Modification (23) twenty-three, effective June 12, 1992, incrementally funded the contract for an additional \$300,000 through November 30, 1992. Total funding was \$6,558,474.

Modification (24) twenty-four, effective August 27, 1992, incorporated an article regarding organizational conflicts of interest.

Letter RFP 1-3-ED-42717 or otherwise known as AP52 (93-11-168-B), dated November 3, 1993, was submitted to ION. A proposal was returned to NASA December 9, 1993. The proposal, with revisions on January 20 and March 11, 1994, was negotiated on March 11, 1994. The negotiated cost was \$3,077,084 and associated fixed fee was \$276,938 for a total of \$3,354,021.

Modification (25) twenty-five, effective January 4, 1993, incrementally funded the contract for an additional \$881,317 through October 15, 1993. Total funding was \$7,439,791.

Modification (26) twenty-six, effective August 24, 1993, changed the contract performance period at no change in total cost based on "Excusable Delays". The extension was through December 31, 1993.

Modification (Change Order) (27) twenty-seven, effective November 3, 1993, incorporated a revision of the contract for an addition to Task H of the SOW. The modification provisionally increased the estimated cost and allocated funds pending subsequent negotiations of ION's proposal described in Letter RFP 1-3-ED-42717. An additional \$445,200 was funded and extended the performance period through March 30, 1994. Total funding was \$7,884,991.

Modification (Change Order) (28) twenty-eight, effective February 18, 1994, incorporated a revision of the contract for an addition to Task H of the SOW. The modification provisionally increased the estimated cost and allocated funds pending subsequent negotiations of ION's proposal described in Letter RFP 1-3-ED-42717. An additional \$205,000 was provisionally funded. Total funding was \$8,089,991.

Modification (Change Order) (29) twenty-nine, effective March 17, 1994, incorporated a revision of the contract for an addition to the Basic Tasks in the SOW. The modification authorized ION to start work on the effort for a period of 120 days and shall not exceed an amount of \$1,239,00 prior to definitization of the modification. ION was ordered to track and report actual costs expended to date on a monthly basis prior to definitization. The report was due by the tenth of each month until definitization. This modification did not increase contract funding. Task L, Environmental Control and Life Support Test Support Services, was incorporated by Modification 29, and was further subdivided as follows:

- Subtask A Physical, Chemical, and Microbial Laboratory Analyses in Support of Integrated Water Recovery Testing
- Subtask B Physical, Chemical, and Microbial Laboratory Analyses in Support of Integrated Air Revitalization Testing
- Subtask C Physical, Chemical, and Microbial Laboratory Analyses in Support of ECLSS Life Testing
- Subtask D Laboratory Analyses in Support of Special Testing
- Subtask E Data Quality Assurance and Transmittal
- Subtask F Database Configuration

Subtask G Sample Collection
Subtask H Provision of Test Subjects

Modification (Change Order) (30) thirty, effective March 16, 1994, initiated subcontract and related effort pending review and signature of a modification resulting from negotiations completed on March 11, 1994. ION was authorized to start work on the effort set forth in Letter RFP 1-3-ED-42717, however, the cost of the effort was not to exceed \$500,000, through May 31, 1994, prior to signature of the definitized modification. Total funding was \$8,589,991.

Modification (31) thirty-one, effective April 12, 1994, provided for an equitable adjustment to the contract as a result of negotiations for changes to the SOW incorporated by Modifications 27, 28, and 30 and certain revisions set forth in Letter RFP 1-3-ED-42717. Provisional increases provided by Modification 27, 28, and 30 were backed out and new funds added in the amount of \$3,241,680. This modification increased the funding amount to \$10,681,471 through May 15, 1994.

Modification (Change Order) (32) thirty-two, effective April 19, 1994, incrementally funded the contract for an additional \$112,341 through June 15, 1995. Total funding was \$10,793,812. The contract was fully funded.

Modification (Change Order) (33) thirty-three, effective June 27, 1994, provisionally increased the estimated cost and funded amounts pending definitization of ION's proposal described in Modification 29. \$1,239,000 was provisionally funded. Contract funding totaled \$12,032,812.

Modification (34) thirty-four, effective June 12, 1994, added the Four Bed Molecular Sieve (4BMS), Vapor Compression Distillation System (VCD), Major Constituent Analyzer (MCA), Liquid Feed Solid Polymer Electrolyzer (LFSPE), and the Detail Test Objective (DTO) Urinal Assembly to the government furnished Property list set forth in Section G.

Modification (Change Order) (35) thirty-five, effective July 28, 1994, provisionally increased the estimated cost and funded amounts pending definitization of ION's proposal described in Modification 29. This action increased the "Not to exceed" amount set forth in Modification 29. An additional \$1,000,000 was provisionally funded. Contract funding totaled \$13,032,812.

Modification (36) thirty-six, effective September 30, 1994, provided for an equitable adjustment to the contract as a result of negotiations for changes to the SOW incorporated by Modification 29. Provisional increases provided by Modifications 33 and 35 were backed out and new funds added in the amount of \$3,073,805. This modification increased the funding amount to \$16,106,617. This action fully funded the contract.

Modification (Change Order) (37) thirty-seven, effective April 18, 1995, provisionally increased the estimated cost and funded amounts pending definitization of a proposal to be submitted on the changed work described in the modification. This action authorized ION to implement the evaluation and development of ECLSS flight

Equipment Urine Processor ERSATZ for the Vapor Compression distillation. \$88,000 was provisionally funded. Contract funding totaled \$16,194,617.

Modification (Change Order) (38) thirty-eight, effective May 17, 1995, extended the performance period through August 31, 1995 pending definitization by change order modification 37.

Modification (Change Order) (39) thirty-nine, effective August 22, 1995, provisionally increased the estimated cost and funded amounts pending definitization of a task extension proposal submitted by ION on August 7, 1995. \$200,000 was provisionally funded. Contract funding totaled \$16,394,617.

Modification (Change Order) (40) forty, effective August 30, 1995, extended the performance period through September 30, 1995 pending definitization by Change Order modification 39.

2.2 Subcontracts

Twenty-eight (28) "major" subcontractors were utilized to implement this contract and 1702 Purchase Orders (PO) let for various supplies. The specific nature of equipment and services required for this contract were set into place by NASA and the prime Space Station contractors prior to ION's involvement in the Space Station Program. This section describes subcontractors, their purpose, deliverables, and contractual events. Table 2.1 lists subcontracted tasks, their task letter, description, vendor, point of contact, subcontract number, performance period, amount, deliverables, and delivery date.

Subcontracts were awarded to The University of Alabama in Huntsville, The University of Alabama at Birmingham,, Research Triangle Institute, Battelle Memorial Institute, Perkin Elmer, Life Systems Inc., Michigan Technological University, United Technologies Hamilton Standard Div., TDA Research Inc., The Boeing Company, McDonnell Douglas Aerospace, Altran Materials Engineering Inc., AlliedSignal Space & Sea Div., and Orbital Sciences Corporation. These subcontracts are discussed in chronological order.

2.2.1 Analytical Control, Task H, NAS8-38250-02

Analytical Control or Analytical Control Coordinator (ACC) was let to The University of Alabama in Huntsville (UAH) (NAS8-3825002) in November, 1989. The contract's scope was "Analytical Control Plan" implementation. The ACC provided ECLSS test data verification for all analyses during test. The ACC was to continually monitor the accuracy and precision of the lab's results by running check samples. The verification check sample values were to be entered into the Freedom ECLSS Database System (FEDS) for tracking and reporting. Weekly status reports, in memorandum form, in addition to monthly reports summarizing the results of work and such other reports as may be reasonably requested were required.

A consent to subcontract was requested, and granted, through the contracting officer.

A Cost Reimbursement (CR) contract was let to UAH with a performance period from November 1, 1989 through September 29, 1990. The estimated cost was \$191,266. Funding was \$145,000.

A termination letter was submitted to UAH on May 30, 1990 due to substandard performance. All property and deliverables, whether complete or not were furnished to ION on June 25, 1990. ION brought the task in-house and continued the task.

2.2.2 Microbial Analyses, Task B, C, & E, NAS8-38250-03

Microbial Analyses was awarded and performed by The University of Alabama at Birmingham (UAB) (NAS8-38250-03). The SOW entailed the analyses of scheduled WRT split samples to validate NASA's main microbial laboratory, Boeing. In addition to the basic effort, contract modifications were executed to expand the SOW.

The contract was incrementally funded \$250,000 of the \$292,000 value. Modification 1 incrementally funded the contract an additional \$19,000. Modification 2 fully funded the contract by adding \$23,000. A letter was sent October 15, 1990 allowing UAB to continue their task since ION was granted their extension. An additional \$19,000 in incremental funds was added. Modification 3 increased the estimated cost from \$292,000 to \$350,000 due to increased sample loads. An additional \$50,202 was incrementally funded. Modification 4 fully funded the contract. Modification 5 exercised UAB's Option 1. This action increased the estimated cost to \$532,760 and funding to \$380,000. Modification 6 incrementally funded the contract \$30,000. Modification 7 incrementally funded the contract \$122,760. Modification 8 incorporated an additional task to the SOW. "Evaluation Of Microbial Contamination Of The Air Filtration Material Aboard The SLS-1 Mission" was implemented. The contract value was increased to \$544,050 and fully funded. Modification 9 incorporated a task entitled "Optimization Of The In-Line Sterilizer". Modification 10 equitably amended the contract amount to fund the changes stated in Mod. 9. The contract value was increased to \$628,252 and funding totaled \$564,050. Modification 12 initiated Option 2 and increased the estimated cost and funding to \$729,427 and \$628,252, respectively. Modification 13 fully funded the contract. Modification 14 was an equitable contract adjustment of three UAB proposals for ECLSS Sample Modification, PCR Modification, and SLS-1 Modification. The estimated cost and funding were both \$916,903.

2.2.3 Medical Monitor, Task K, NAS8-38250-04

The Medical Monitor task was awarded to UAH (NAS8-38250-04) in March, 1990. The contract's scope was to provide medical services with a qualified physician to support the ongoing ECLSS Water Recovery Test. The basis tasks to be performed were:

- Respond to medical questions raised during testing and advise MSFC's principal investigator and test director on medical issues.
- Assist in certification of water produced in testing.
- Assist in training personnel with regard to medical requirements.

A Cost Plus (CP) contract was let to UAH with a performance period from March 1, 1990 through June 30, 1990. The estimated cost was \$14,576. Funding was \$14,576.

The contract was completed on September 28, 1990 with final report receipt.

2.2.4 TOC Accountability, Task B, C, & E

This task was awarded to two independent laboratories for Quality Assurance (QA) purposes. Battelle Memorial Institute (BMI) and Research Triangle Institute (RTI) performed qualitative and semiquantitative Total Organic Carbon Accountability (TOCA) of hygiene, condensate, and potable waters from the WRT and Spacelab missions.

Monthly reports summarizing the results and a final report were required.

2.2.4.1 Research Triangle Institute, NAS8-38250-05

The contract was a CPFF with an estimated base cost of \$57,966 and one Option year at a cost of \$10,519 for a total contract value of \$68,485. Modification 1 granted the option period. Modification 2 fully funded the contract.

2.2.4.2 Battelle Memorial Institute, NAS8-38250-06

The contract was a CPFF with an estimated base cost of \$142,054 and one Option year at a cost of \$25,779 for a total contract value of \$167,833. Modification 1 granted the option period. Modification 2 fully funded the contract at \$167,833. Modification 3 provided an equitable adjustment for expanded analyses. The contract estimated cost and fixed fee were \$280,825 and \$27,822, respectively. Modification 4 incrementally funded the contract, \$308,647. Modification 5 extended the contract performance period. Modification 6 granted the option performance period. Modification 7 provided for an equitable adjustment to the contract as a result of negotiations for additions to the SOW. The estimated cost and fixed fee were increased to \$462,192 and \$42,331, respectively. Modification 8 fully funded the contract at \$504,523. Modification 9 descope the contract (\$30,368). Modifications 10 and 11 extended the performance period. Modification 12 provided an equitable adjustment for changes to the SOW. The contract was fully funded and estimated cost and fee totals were \$449,548 and \$41,510, respectively.

2.2.5 Monitoring of Water Reclamation Using Predictive Statistics, Task K, NAS8-38250-07

The Monitoring of Water Reclamation Using Predictive Statistics task was awarded to UAH (NAS8-38250-04) in March, 1990. The contract's scope required monthly reports summarizing the results of work and such other reports as requested were required.

- Explored the use of multivariate statistical techniques.
- Developed and demonstrate the use of multiple sensors and multivariate calibration techniques.
- Integrate laboratory investigations and inline and classical chemical analyses at the earliest opportunity.

- Investigated the use of predictive statistical algorithms for calibration of inline and online data in units of water quality.

A Cost Plus (CP) contract was let to UAH with a basic performance period from September 1, 1990 through October 15, 1990. An option period from October 16, 1990 through August 30, 1991 was available for continued work. The estimated cost was \$21,730.38 and \$152,112.62 for the Base and Option periods, respectively. Funding was \$21,730.

Modification 1, Option period, was exercised on October 15, 1990 with no additional funds. Modification 2 added \$21,000 incremental funding. Modification 3 added \$20,000 incremental funding. On February 14, 1991 a stop work order was issued due to funding limitations. On March 18, 1991 the contract was terminated due to "Limitation of Funds".

2.2.6 Vapor Compression and Distillation System Upgrade, Task H, NAS8-38250-08

Life Systems, Inc. was awarded the Vapor Compression and Distillation System Upgrade. The CPFF contract had initial provisional funding of \$50,000. The contract was initiated prior to negotiations due to NASA scheduled milestones. Modification 1 was executed after negotiations which yielded an estimated cost of \$337,746 and fixed fee of \$30,059 for a total value of \$367,805. The contract was incrementally funded \$100,000. The performance period was March 15, 1992 through October 15, 1992. Modification 2 amended the contract deliverables and incrementally funded the contract an additional \$267,805. Modification 3 extended the contract through October 15, 1993. Modification 4 made an equitable contract adjustment for SOW additions and increased the estimated cost, fixed fee, and funding to \$342,835; \$30,512; and \$373,347, respectively.

2.2.7 Viable Microbial Monitor, Task J-2, NAS8-38250-09

Perkin-Elmer, Applied Science Operation, was awarded a CPFF contract to study an inline monitor for viable microorganisms in spacecraft potable water applications. Monthly reports summarizing the results of work were required. The estimated cost and fixed fee were \$239,254 and \$16,595, respectively. Modifications 1 and 2 extended the performance period at no additional cost.

2.2.8 Unibed Model Development, Task J-6, NAS8-38250-10

This task was awarded to Michigan Technological University (MTU) on March 5, 1993. The SOW entailed the development and verification of the Space Station Freedom multifiltration computer model. Monthly reports and a final report were required. This cost reimbursement contract had a performance period through October 15, 1993 and an estimated cost of \$178,654. Modification 1 extended the contract through December 15, 1993 at no additional cost.

2.2.9 VCD Flight Assessment, Task J-3, and VCD Flight Experiment, Task J-9, NAS8-38250-11

This CPFF contract was awarded to LSI on March 16, 1994. The estimated cost and fixed fee were \$277,435 and \$22,195, respectively. The performance period was March 16, 1994 through September 15, 1994. The initial award letter incrementally funded the contract \$99,100. The SOW entailed the assessment of VCD Flight Experiment only. LSI investigated and defined necessary unit modifications, established objectives, requirements, specifications and defined the level of detail to develop a full-size mock-up. Monthly and a final report were required. Modification 1 fully funded the contract. Modification 2 revised the SOW to incorporate Task J-9, VCD Flight Experiment through PDR, and made an equitable adjustment increasing the estimated cost, fixed fee, and funding to \$491,576; \$41,254; and \$399,630, respectively. Modification 3 extended the performance period through December 31, 1994. Modification 4 extended the performance period through March 15, 1995. Modification 5 fully funded the contract. Modification 6 extended the performance period through March 30, 1995. Modification 7 extended the performance period through May 31, 1995.

2.2.10 Mostly Liquid Separator Development, Task H-6 and Process Pump Development, Task J-1, NAS8-38250-12

United Technologies, Hamilton Standard Division, was awarded a CPFF contract to: (A) Develop a Process Pump; and (B) Develop a Mostly Liquid Separator (MLS). Deliverables included a prototype MLS, monthly reports, and a final report. The negotiated estimated cost and fixed fee were \$459,013 and 38,804 respectively. The performance period was March 15, 1994 through April 15, 1995. Modifications 1, 2, 3, and 4 incrementally funded the contract \$32,085; \$62,085; \$170,345; and \$190,345, respectively. Modification 5 fully funded the contract at \$497,817. Modification 6 extended the performance period at no additional cost through June 15, 1995.

2.2.11 PCWQM Development, Task H, NAS8-38250-13

ASTRO International was awarded a Firm Fixed Price (FFP) contract to fabricate and deliver a Process Control Water Quality Monitor (PCWQM). The FFP was \$274,872. The PCWQM was delivered July 6, 1994.

2.2.12 Spacelab Charcoal Analyses, Phase II, Task D-1, NAS8-38250-14

Spacelab Charcoal Analyses, Phase II was awarded to Battelle Memorial Institute (BMI). A CPFF contract began March 16, 1994. The estimated cost, exclusive of fixed fee was \$42,875. The fixed fee was \$3,355. The SOW was to analyze charcoal samples from four Spacelab missions' Trace Contaminant Removal Systems for polar compounds and submit a final report. Monthly reports summarizing the results of work were required. Modifications 1 and 2 extended the performance period to July 30, 1994 and August 31, 1994, respectively. Modification 3 fully funded the contract. Modification 4 extended the performance period at no additional cost. Modification 5 made an equitable adjustment to the contract as a result of an RFP in the amount of

\$3,284. The RFP's SOW, "Analyses of samples for Trimethylamine", was also incorporated. The estimated cost was \$45,920 and fixed fee was \$3,594. The contract was also fully funded at \$49,514.

2.2.13 TCCS Catalyst Bench Test, Task J-12, NAS8-38250-15

This was awarded to TDA Research on March 16, 1994. The contract was a CPFF type and had an estimated cost of \$201,729 and fixed fee of \$12,527. The performance period was through May 30, 1995. Initial contract funding was \$33,042 through May 30, 1994. The SOW involved determining the number of poisoning/recovery cycles the Trace Contaminant Control System (TCCS) catalyst could tolerate before its efficiency fell below 10%. Monthly reports and a final report were required. Modification 1 extended the funding limitation period through June 30, 1994. Modification 2 incrementally funded the contract to \$90,042. Modification 3 extended funding limitation period through September 30, 1994. Modification 4 fully funded the contract at \$214,256.

2.2.14 VRA Procurement, Task H-4, NAS8-38250-16

United Technologies, Hamilton Standard Division was awarded a CPFF contract on March 16, 1994. The estimated cost was \$79,158 and fixed fee \$7,079. The contract procured a volatile Removal Assembly (VRA) reactor for the Water Processor (WP). The performance period was through July 30, 1994. Initial funding was \$43,118 through May 30, 1994. Modification 1 extended the funding period through June 30, 1994. Modification 2 fully funded the contract. Modification 3 incorporated additions to the SOW for additional testing and extended the contract through August 17, 1994 at no additional cost. The VRA was delivered and accepted on August 17, 1994.

2.2.15 Molecular Sieve Bench Test and Computer Modeling, Task J-5, NAS8-38250-17

A CPFF contract was awarded to McDonnell Douglas Aerospace on March 17, 1994. The estimated cost and fixed fee were \$77,885 and \$7,756 respectively. The performance period was through January 30, 1995. The SOW entailed continued development of an analytical model of the Four Bed Molecular Sieve (4BMS). Monthly reports and a final report were required. Modification 1 fully funded the contract. Modification 2 extended the performance period through March 31, 1995 at no additional cost. Modification 3 extended the performance period through April 30, 1995 at no additional cost. A verified model was delivered April 30, 1995.

2.2.16 VRA Computer Modeling, Task H-4, NAS8-38250-18

Michigan Technological University (MTU) was awarded a Cost Reimbursement (CR) contract on March 16, 1994. The estimated cost was \$103,857 with a performance period through December 30, 1994. The contract had an option period totaling \$80,333. Initial contract funding was \$19,310 through May 30, 1994. The SOW described the development of a computer model that would simulate the performance of the catalytic oxidation reactor and a final report detailing the effort. Modification 1 extended the funding limitation period through June 30, 1994. Modification 2

incrementally funded the contract an additional \$40,000 through August 30, 1994. Modification 3 fully funded the contract. Modification 4 provided an extension at no additional cost through February 28, 1995. Modification 5 extended the contract's performance period through April 15, 1995.

2.2.17 Laboratory and Test Subject Support, Task L, NAS8-38250-19

A Level of Effort (LE) contract was awarded to The Boeing Company, Boeing Defense and Space Group, April 12, 1994 totaling \$709,460. The contract's initial funding was \$188,607. The SOW described analytical and test subject tasks to be conducted for integrated WR and AR tests. The performance period was through October 30, 1994. Data transferred to the Marshall Information Network System One (MINS1) and monthly labor schedules were deliverables. Modification 1 incorporated an Option period, from November 1, 1994 through February 28, 1995, and incremental funding totaling \$340,103. The Option value was \$579,808. Modification 2 authorized an increase in staff and overtime utilization. Modification 3 incrementally funded the contract an additional \$164,902. Modification 4 incrementally funded the contract \$204,455. Modification 5 exercised the Option and fully funded the contract.

2.2.18 Microbial Surface Growth, Task G-3, NAS8-38250-20

A CPFF contract was let to Altran Materials Engineering, Inc. on October 6, 1994 for an estimated cost of \$92,421 and fixed fee of \$4,621. The performance period was through April 10, 1995. The SOW entailed the test of Space Station materials for biodeterioration and estimate the degree of potential problems. Monthly reports and a final report were required. Modification 1 extended the contract's performance period through June 15, 1995.

2.2.19 SFE IV-A Refurbishment, Task H-9, and WRT/ART Support, Task J-10, NAS8-38250-21

Life Systems, Inc. (LSI) was awarded a CPFF contract on March 28, 1994. The contract was initially funded \$85,000 through May 31, 1994. Modification 1 made an equitable contract adjustment after negotiations. The negotiated estimated cost and fixed fee were \$679,636 and \$60,488. The contract was delivered June 16, 1994 with a performance period through April 30, 1995. The SOW entailed: (A) modification of the Static Feed Electrolyzer IVA subsystem (SFE-IVA) for ART; and (B) AR technical support. A refurbished SFE-IVA, monthly reports and a Final Report were deliverables. Modification 1 incrementally funded the contract. Modification 2 provided an equitable adjustment for an optional task. The new estimated cost, fixed fee, and funding were \$738,789; \$65,753; and 449,418, respectively. Modification 3 extended the limitation of funds performance period through August 31, 1994. Modification 4 extended the limitation of funds performance period through October 15, 1994. Modification 5 fully funded the contract and changed the SFE-IVA delivery date to March 22, 1995. Modification 6 changed the SFE-IVA delivery date to April 22, 1995.

**2.2.20 LFSPE Refurbishment, Task H-11, and WRT/ART Support,
Task J-10, NAS8-38250-23**

A CPFF contract was awarded to United Technologies, Hamilton Standard Division on May 20, 1994. The total estimated cost and fixed fee were \$373,873. The performance period was through May 15, 1995. Deliverables included a refurbished Liquid Feed Solid Polymer Electrolyzer (LFSPE), technical support, and monthly and final reports. New cost certifications were obtained by Hamilton Standard which increased the contract value to \$374,584. Modification 1 incrementally funded the contract and initiated Task A. Modification 2, a change order, amended the SOW to add additional technical support hours. Modification 3 provided an equitable adjustment of \$4,773 for Modification 2 changes. Modification 3 fully funded the contract for \$379,357. The LFSPE scheduled delivery was June 15, 1995.

**2.2.21 4BMS Blower Procurement, Task H-12, and ART Support
Task J-10, NAS8-38250-24**

AlliedSignal, Inc. was awarded a CPFF contract in the amount of \$170,639. The performance period was through May 15, 1995. An Option period was costed at \$39,034. Deliverables included a 4BMS blower, technical support, and monthly and a final report. Incremental funding totaled \$88,000. Modification 1 provided full funding.

2.2.22 POST 4BMS Modifications, Task H-13, NAS8-38250-25

AlliedSignal Inc., was awarded a CPFF contract in the amount of \$51,000. The performance period was through January 30, 1995. Deliverables included a fully modified Carbon Dioxide Removal Assembly (CDRA) software, operation manual, and a final report. Modification 1 extended the performance period through May 31, 1995 at no additional cost. Modification 2 decreased the performance period through March 31, 1995.

**2.2.23 MCA Checkout and Repair, Task H-14, and ART Support,
Task J-10, NAS8-38250-26**

Orbital Sciences Corporation (OSC) was awarded a CPFF contract to repair the Major Constituant Analyzer (MCA). After repairs, OSC verified nominal operation, changed the pump oil, and prepared a final report. The contract was let for an estimated cost of \$81,753 and associated fixed fee of \$7,358. Modification 1 extended the contract's performance period. Modification 2 deleted the requirement for financial management reports. Modification 3 made an equitable contract adjustment based on Modification 2's report deletions. The estimated cost and fixed fee were \$73,941 and \$6,655, respectively.

**2.2.24 Unibed Model Development - Phase II, Task J-6,
NAS8-38250-27**

Michigan Technological University was awarded a cost Reimbursement (CR) contract on April 29, 1994. The estimated cost was \$309,429 with a performance period

through May 15, 1995. In addition to the basic effort there was a 3 month Option period priced at \$108,701. The SOW entailed continued development of a unibed model that would culminate in the delivery of a computer program capable of simulating the performance of the SS single loop unibed for processing waste shower/handwash water. Bimonthly progress reports, a final report, a final program user's guide, and computer model were deliverables. Initial contract funding was \$50,000. Modification 1 incrementally funded the contract an additional \$50,000. Modification 2 exercised the Option, made an equitable adjustment due to SOW descope, and fully funded the contract at \$393,506.

2.2.25 Urine Pretreatment Development, Task J-7, NAS8-38250-28

A CPFF contract was awarded to United Technologies, Hamilton Standard on August 19, 1994. The contract had an estimated cost of \$139,390 and fixed fee of \$12,766. The contract's performance period was through April 1, 1995. Initial contract funding was \$50,000. The SOW entailed evaluating various urine pretreatment methods for the SS Waste Management System (WMS) through a trade study and testing. Contract deliverables included prototype urine pretreatment hardware and monthly technical progress reports. Modification 1 fully funded the contract at \$152,156. Modification 2 extended the performance period, at no additional cost, through June 15, 1995.

2.2.26 SFE Flight Experiment Through PDR, Task J-8, NAS8-38250-29

A CPFF contract was awarded to Life Systems, Inc. on May 2, 1994. The estimated cost and fixed fee were \$466,035 and \$41,477, respectively. The SOW detailed the development of a preliminary design for the Static Feed Electrolyzer (SFE) flight experiment. Deliverables included monthly technical reports, a project plan, a preliminary design program final report, and a full size mock-up. The contract's performance period was through January 31, 1995. Initial contract funding was \$141,200 through July 30, 1994. Modification 1 extended the contract's performance period through March 30, 1995, at no additional cost. Modification 2 extended the funding limitation period through October 15, 1994. Modification 3 fully funded the contract at \$507,512. Modification 4 extended the contract's performance period through May 31, 1995.

2.2.27 Polymerase Chain Reaction Assessment, Task J-13, NAS8-38250-2695

PCR assessment was awarded to The University of Alabama at Birmingham (UAB). The contract's tasks were to evaluate PCR limitations, including detection limits, sensitivity, time of detection, and complexity of the technology through literature searches. The contract cost and funding were \$49,654, completion was June 15, 1995.

3.0 TECHNICAL

The following sections provides summaries of the tasks outlined in the contracts' SOW, "Section J".

3.1 Support and Development

ION provided resources dedicated to assessing ECLSS WRT and life test results and publishing of test reports. Over 8400 hours of engineering manpower were used for direct ION support and development.

ION has been partially and/or solely responsible for the production of numerous NASA reports and technical documents. In addition, ION generated reports have been used in the development of NASA final reports and Technical Memorandums (TMs). The following is a list of documents produces during this contract's performance period.

- *Analytical Control Coordinator Standard Operating Procedure*, ION Electronics (NAS8-38250), J. Tataara, June 1990.
- *Analytical Control Test Plan for Water Recovery Testing, Version 2.0*, ION Electronics (NAS8-38250), J. Tataara, February 1990.
- *Analytical Control Summary Report, Stages RC & MC*, ION Electronics, (NAS8-38250), J. Tataara, September 1991.
- *Analytical Control Test Plan and Microbiological Methods for Water Recovery Testing, Version 3.0*, ION Electronics (NAS8-38250), J. Tataara, May 1991.
- *Analytical Control Test Plan and Microbiological Methods for Water Recovery Testing, Version 3.1*, ION Electronics (NAS8-38250), J. Tataara, August 1991.
- *Analytical Support for the Environmental Control and Life Support System (ECLSS) on the Space Station Freedom Project*, Research Triangle Institute (ION Electronics, NAS8-38250-05), October 1991.
- *Boeing Laboratory Audit*, ION Electronics (NAS8-38250), J. Tataara, October 1991.
- Davidson, M. W., ION Electronics; Slivon, L., Battelle Memorial Institute; Sheldon, L., Research Triangle Institute; and Traweek, M., NASA MSFC, *Space Station Freedom Water Recovery Test Total Organic Carbon Accountability*, (ION Electronics, NAS8-38250), ICES, San Francisco, CA, July 1991.
- *Description of Microorganisms Identified During Stage A of the Environmental Control and Life Support System Water Recovery Test*, The University of Alabama at Birmingham (ION Electronics, NAS8-38250-03), July 1991.
- *Detection and Characterization of Microbial Contaminants Acquired During Water Sample Collection in the Area of the Water Recovery Test*, The University of Alabama at Birmingham (ION Electronics, NAS8-38250-03), July 1991.
- *Forensic and Microbiological Examination of Debris from Air Filtration Systems Aboard the Spacelab Life Science 1 Module*, The University of Alabama at Birmingham (ION Electronics, NAS8-38250-03), August 16, 1991.
- *Microbial Characterization of Shower, Clotheswash and Handwash Wastewater Obtained from the End-Use Equipment Facility*, The University of Alabama at Birmingham (ION Electronics, NAS8-38250-03).
- *Total Organic Carbon Accountability Study, Phase A Evaluation of Samples Obtained from WRT Test 3A*, Battelle Memorial Institute (ION Electronics, NAS8-38250-06), January 9, 1991.

- *Total Organic Carbon Accountability Study, Phase A Evaluation of Samples Obtained from WRT Test 3B*, Battelle Memorial Institute (ION Electronics, NAS8-38250-06), March 22, 1991.
- *Total Organic Carbon Accountability, Phase A Evaluation of the Third Sample Set*, Battelle Memorial Institute (ION Electronics, NAS8-38250-06), August 26, 1991.
- *Analytical Control Summary Report, Stages 4 & 5*, ION Electronics (NAS8-38250), J. Tatara, February 1992.
- *Analytical Control Summary Report, Stage 7*, ION Electronics (NAS8-38250), J. Tatara, July 1992.
- *Analytical Control Test Plan and Microbiological Methods for Water Recovery Testing, Version 3.2*, ION Electronics (NAS8-38250), J. Tatara, September 1992.
- *Boeing Laboratory Audit*, ION Electronics (NAS8-38250), J. Tatara, August 1992.
- *Identification of Microorganisms by Polymerase Chain Reaction During Stage 7 of the Water Recovery Test*, The University of Alabama at Birmingham (ION Electronics, NAS8-38250-03), July 1992.
- *Operation and Procedure manual with Subsystem Control Software - Upgrade of VCD-IV to Post Equivalent*, Life Systems Inc., (ION Electronics, NAS8-38250-08), September 30, 1992.
- Tatara, J. D. and Minton, S.A, *The Analytical Control Program for the NASA Space Station Freedom Environmental Control and Life Support System (ECLSS) Water Recovery Test*, SAE # 921269, ION Electronics (NAS8-38250), International Conference on Environmental System (ICES), Seattle, WA, July 1992.
- *Total Organic Carbon Accountability, Phase A Analysis of the Stage 4*5 Sample Set*, Battelle Memorial Institute (ION Electronics, NAS8-38250-06), February 1992.
- *Total Organic Carbon Accountability, Phase A Analysis of the Stage 7 Sample Set*, Battelle Memorial Institute (ION Electronics, NAS8-38250-06), February, 1992.
- *Analytical Method for Sodium Dodecylbenzenesulfonate (SDBS) and Sodium N-Coconut Acid-N-Methyltaurine (SCMT) in ECLSS Water Recovery Process*, Battelle Memorial Institute (ION Electronics, NAS8-38250-06), August 19, 1993.
- *ECLSS Life Test Quarterly Report #1*, ION Electronics, (NAS8-38250), Tatara, Chiu, & Salyer, July 1993.
- *Evaluation of Air Filtration Aboard the SLS-1 Mission --Comparison with Exemplar Standard Materials*, The University of Alabama at Birmingham (ION Electronics, NAS8-38250-03), April 16, 1993.
- *In-line Sterilization of Wastewater for Space Station Freedom: Heat Resistance of Microorganisms*, The University of Alabama at Birmingham (ION Electronics, NAS8-38250-03), June 4, 1993.
- *Spacelab Trace Contaminant Removal System Charcoal Analyses, IML and USML*, Battelle Memorial Institute, (ION Electronics, NAS8-38250-14), September 1993.
- *Total Organic Carbon Accountability, Phase A Analysis of the Spacelab IML-1 Humidity Condensate Sample*, Battelle Memorial Institute (ION Electronics, NAS8-38250-06), January 1993.
- *Total Organic Carbon Accountability, Phase A Analysis of the Stage 7 Sample Set*, Battelle Memorial Institute (ION Electronics, NAS8-38250-06), January 1993.
- Chiu, COY., J.L. Perry, B.H. Salyer, and J.D. Tatara, *Preliminary Results of NASA ECLSS Life Testing*, SAE #941463, (NASA ED62/ION Electronics), 24th ICES, Friedrichshafen, Germany, June 20-23, 1994.

- Chiu, COY., B.H. Salyer, and J.D. Tatara, *ECLSS Life Test Quarterly Report #5*, ION Electronics (NAS8-38250), July 1994.
- Perry, JCL., COY. Chiu, B.H. Salyer, and J.D. Tatara, (NASA ED62/ION Electronics) *ECLSS Life Testing Program Status*, MSFC, August 1994.
- Chiu, COY., B.H. Salyer, and J.D. Tatara, *ECLSS Life Test Quarterly Report #6*, ION Electronics (NAS8-38250), October 1994.
- Traweek, M., and J. Tatara, *Analytical Control Test Plan and Microbiological Methods for Water Recovery Testing*, (NASA TM #108473), ION Electronics (NAS8-38250), December 1994.
- Perry, JCL., and J. Tatara, *International Space Station Alpha Trace Contaminant Control Subassembly Life Test, Final Report*, (NASA TM), ION Electronics (NAS8-38250), March 1995.
- *Operation and Maintenance Manual (4BMS)*, AlliedSignal, June 1995
- *Final Report ISSA Carbon Dioxide Assembly Modification*, AlliedSignal, June 1995
- *Preliminary Design Program Final Report (SFE)*, Life Systems, June 1995
- *Preliminary Design Program Final Report (VCD)*, Life Systems, June 1995
- *Assessment of Microbial Degradation of Space Station Materials, Task A*, Altran Materials Engineering, June 1995
- *Spacelab Charcoal Analyses - Phase II*, Battelle Memorial Institute, June 1995
- *Volatile Removal Assembly Model Final Report*, Michigan Technological University, June 1995
- *SPE Oxygen Generator Assembly Operations Manual*, (SPE OGA, Rev. Basic), Hamilton Standard, June 1995
- *Software Requirements Specification for the SPE, Process Controller* (SVHSER16750, Rev. -), Hamilton Standard, July 1995
- *Software Top-Level Design document for the SPE, Process Controller* (SVHSER16751, Rev. -), Hamilton Standard, July 1995
- *Software Top-Level Design Document for the SPE, Command & Display Unit* (SVHSER16749, Rev. -), Hamilton Standard, July 1995
- *Software Requirements Specification for the SPE, Command & Display Unit* (SVHSER16748, Rev. -), Hamilton Standard, July 1995
- *Material Identification and Usage Listing for the SPE* (SPE OGA MIUL, Rev. Basic), Hamilton Standard, July 1995
- *Safety Hazard Analysis for the SPE* (SPE OGA SHA, Rev. Basic), Hamilton Standard, July 1995
- *Failure Mode and Effects Analysis for the SPE* (SPE OGA SHA, Rev. Basic), Hamilton Standard, July 1995
- *Unibed Model Final Report, Phase I*, Michigan Technological University, August 1995
- *Assessment of Microbial Degradation of Space Station Materials, Task B Report*, Altran Materials Engineering, August 1995
- *PCR Based Microbial Monitor for Analysis of Recycled Water Aboard the ISSA Final Report*, The University of Alabama in Birmingham, August 1995
- *SPE Oxygen Generator Assembly (OGA) Final Report Rev. A*, Hamilton Standard, September 1995
- *Urine Pretreat Injection System Final Report*, Hamilton Standard, August 1995
- *Space Station Water Processor Mostly Liquid Separator (MLS) Final Report*, Hamilton Standard, August 1995

- Space Station Water Processor Process Pump Final Report, Hamilton Standard, August 1995
- Enhanced Urine Ersatz Development and Testing Final Report, Life Systems Inc., August 1995
- Static Feed Electrolyzer (SFE) Final Report, Life Systems Inc., Pending - October 1995
- 4BMS Blower Fabrication Final Report will be delivered under NAS8-40369

3.1.1 Analytical Control, Task H, NAS8-38250-02

Key to the success of this contract was the evaluation of ECLSS test results via sophisticated laboratory analysis capabilities. ION utilized CH2M HILL, UAB, and BMI analytical services for detailed physical, chemical, and microbiological assessments. This capability was vital to proper ECLSS testing, and, as such, the validity of these evaluations was subject of close scrutiny by NASA.

The analytical control plan implemented by ION was supplied by the NASA and defined the "screening" approach used by ION in selecting participating laboratories. Laboratories chosen to provide ECLSS testing support had an active quality assurance (QA)/quality control (QC) program. The laboratories continually monitored the accuracy and precision of results reported by running check samples, matrix spikes, surrogate spikes, duplicates, etc. to determine reliability. In addition control charts for accuracy and precision were made for each analyte to determine when the system was out of control. The QA program used in the laboratory was to reviewed by NASA through audits.

The results of each analyte (ions, metals, organics, etc.) reported to NASA was accompanied by a statement of accuracy and precision for the method used. Where applicable, the same requirement was implemented for physical property and microbial analyses.

The ACC provided ECLSS test data verification for all chemical analyses during the WRT. The ACC continually monitored the accuracy and precision of the lab's results by running check samples. The verification check sample values were entered into the Freedom ECLSS Database System (FEDS) for tracking and reporting. Weekly status reports, in memorandum form, in addition to monthly reports summarizing the results of work were submitted.

Laboratory audits were performed during test. No audit deficiencies were found. An audit report was submitted to ED62 after each audit.

3.1.2 Microbial Analyses, Task B, C, & E, NAS8-38250-03

ION qualitatively and quantitatively assessed water, air, and solid samples generated during ECLSS test activities for microbiological organisms. 1062 samples were submitted to UAB for microbial assessment. The sample results were compared to the NASA WRT laboratory for accuracy and reproducibility. The comparisons were generally within 1 order of magnitude which was acceptable for microbial cultures.

3.1.2.1 Optimization of the In-Line Sterilizer for Space Station Water Recovery and Management Subsystem

The SOW addressed activities to optimize the performance of the in-line sterilizer baselined for use in the Space Station Recovery and Management (WRM) System. This device was used to sterilize potable and hygiene waste waters prior to being recovered by the Potable Water Processor (PWP) and the Hygiene Water Processor (HWP).

The SOW was divided into two phases. Phase I required the microbial characterization of the waste waters to be sterilized. This characterization concentrated on the potential thermophiles found in the waste waters. Phase II required the performance of a series of tests, using the information on phase I, which determined the optimum operating parameters for the in-line sterilizer.

The efforts to optimize the in-line sterilizer centered around two main operational parameters; sterilization temperature and hold time. From the characterization information developed in phase I, a "design" microorganism was selected for use in the phase II testing. Using the design microorganism, a series of bench tests were performed at varying hold times and temperatures. Recommendations for the optimum sterilization temperature and hold time that the in-line sterilizer needs to operate at in order to provide sterile water were reported.

3.1.2.2 Microbial, and Forensic Assessments of Solid Samples

ION performed qualitative and quantitative physical and microbial assessments of solid samples generated during ECLSS test activities. These assessments were generally unique in nature and included, but were not be limited to, quantification of solid masses accumulated on filter elements, qualitative and quantitative analyses of chemical contaminants adsorbed on activated carbon or other sorbent materials, enumeration of bacteria isolated from filters and adsorption columns, and scanning electron microscopy of selected test surfaces in order to examine for signs of corrosion, contamination or biofilm formation. These types of assessments were kept to a minimum. The actual types and numbers of assessments were determined by NASA based on test objectives, conditions, and previous test results as well as specific space flights of the Shuttle/Spacelab.

3.1.3 Medical Monitor, Task K, NAS8-38250-04

ION provided medical consultant services with a qualified physician to support the on-going ECLSS WRT. The basis task performed were as follows:

- Reviewed and commented on test protocols specifically in the medical areas.
- Responded to medical questions raised in testing and advised MSFC's principal investigator and test director on medical issues.
- Assisted in certification of water produced in test.

- Assisted in training personnel with respect to medical requirements.
- Provided advice to MSFC's Institutional Review Board (IRB) on test subject safety related to medical issues.
- Assisted in reviewing and signing advised consent forms of test subjects.

3.1.4 TOC Accountability, Task B, C, & E

ION was required to perform special research work in the laboratory related to identifying and quantifying particular compounds in the WRT water samples. This research was semi-qualitative where an unknown compound was only tentatively identified because an analytical method has not been developed for qualitatively and quantitatively defining the compound. In addition, research was required to develop specific methods for analyzing compounds identified by NASA where no known process or method existed. Other research included the identification of total organic compounds found in the reclaimed ECLSS test water.

Past analyses of Spacelab humidity condensate have yielded low Total Organic Carbon (TOC) accountability. MSFC's ultimate goal was to quantitatively account for 80 to 90% of organic compounds present in humidity condensate, hygiene water and potable waters from the WRT and in humidity condensate from Spacelab. Due to the complexity of this task, characterization of these water types was planned in two phases.

The focus of Phase A was qualitative analyses. Semi-qualitative data was encouraged, but precise quantitative determinations of contaminants was not required. The laboratory received condensate, hygiene, and potable waters from the WRT. The laboratories also received humidity condensate from Spacelab missions. The labs determined which instrumental analyses/procedures were appropriate and necessary to discover all carbon contaminants present.

Phase B sought near-complete, quantitative characterization of all four types of water. Methods were developed to quantify organic compounds identified in Phase A. All developed methods were verified as outlined in the ACC plan. The final report included methods and instruments used, detection limits, pre-concentration techniques, and results of verification data.

3.1.5 Monitoring of Water Reclamation Using Predictive Statistics, Task K, NAS8-38250-07

The initial 5 months of work emphasized test design, setup and initial evaluation of exploring the use of multivariate statistical techniques. UAH determined that these techniques were a viable scientific means of assisting in evaluating ECLSS waste water data. The contract stopped due to funding limitations. Potential future research is possible in this area. The other 3 areas defined in the SOW were not addressed in the initial 5 months of the contract.

3.1.6 Vapor Compression and Distillation System Upgrade, Task H, NAS8-38250-08

This task addressed the modification and updating of the Vapor Compression Distillation (VCD) urine reclamation hardware for the government as well as provide engineering support for the modified subsystem. ION upgraded the VCD-IV subsystem, used in MSFC/Boeing comparative test, to the January 1993 SSF design configuration. Design documentation and rationale for design modifications, including subsystem control software, to support the changes was provided.

3.1.7 Viable Microbial Monitor, Task J-2, NAS8-38250-09

Perkin-Elmer provided personnel, equipment and facilities pursuant to the study of an inline monitor for viable microorganisms in spacecraft potable water applications for NASA. Perkin-Elmer utilized Viable Microbial Monitor (VM²) technology for this study. Development of VM2 technology is not part of this effort.

This effort focused on development of single WRT organism methodologies. Methods were developed for analyzing approximately ten WRT bacteria using optimized instrumental techniques and culture conditions. Three of the most responsive bacterial methodologies were chosen for further characterization.

A number of microorganisms have been isolated from many manned space flight missions including various Apollo, Space Shuttle and Spacelab missions. In addition simulation of the closed loop space-borne potable water system by MSFC in the Space Station Freedom Water Recovery Test program.

ION provided data regarding microorganisms which have been isolated in previous manned space flight operations and which have been isolated in SSF WRT. Perkin Elmer assisted in selecting from this list approximately ten microorganisms which were studied. ION provided samples of selected microorganisms from those isolated in space flight WRT operations.

Perkin Elmer researched available literature to determine appropriate media and temperatures for culture of the selected organisms.

Each microorganism was subjected to a series of test to determine growth characteristics. Protocols for each species specified three culture media and three temperature variables to determine optimum performance. Four dilutions of Stock WRT bacteria and blanks were replicated a minimum of three times.

After the data was reviewed 5 microorganisms were selected for further study. The species selected were:

Klebsiella oxytoca
Bacillus subtilus
Pseudomonas cepacia

Staphylococcus epidermidis
Corynebacterium xerosis

A final report and presentation were provided in June 1993.

3.1.8 Unibed Model Development; Task J-6, NAS8-38250-10

The water processor design for the SSF Water Recovery and Management (WRM) Subsystem employed multifiltration technology for the removal of contaminants from Environmental Control and Life Support (ECLS) waste waters. Multifiltration technology utilized a series of ion exchange resins and carbonaceous adsorbents packaged into a unibed in an order designed to achieve optimal contaminant removal. The importance of the unibed in the design of the WRM led to the necessity to predict its performance and life. An effort to develop an analytical model of the potable humidity condensate unibed was completed by Michigan Technological University (MTU) under McDonnell Douglas Space Systems Company contract SK90A049 (Development of a Mathematical Model to Evaluate the Operation of the Multifiltration Unit in the Space Station's Drinking Water Treatment System). Though useful, the effort was only a first attempt at developing a model of a complex phenomena. The effort did help define what steps should be taken towards the development of a model that can be used in the development and/or troubleshooting of the SSF Environmental Control and Life Support System's (ECLSS) WRM. Accordingly, the SOW requested a proposal from MTU for additional unibed modeling that culminated in the delivery of a computer program capable of simulating the performance of a SSF single loop unibed. The following defines the scope of the proposal.

The final model is capable of:

Defining unibed performance in terms of contaminant removal efficiency and life expectancy with varying input conditions. These input conditions include varying the composition of the combined waste stream (i.e., varying quantities of the individual waste streams) and varying the contaminant concentration profile in each of the individual waste streams. The individual waste and their anticipated contaminant load were defined in a table containing the various waste water sources and chemical make up. The model is capable of accepting changes to the input conditions at varying waste water constituencies, each processed through the unibed for a defined period based on throughput. The throughput for each waste water constituency is defined by the end user.

Though the contaminants expected to be present in the waste water were defined, the model is able to estimate the unibed's capability to remove a contaminant based upon a set of specified contaminant properties (e.g., molecular weight, solubility, etc.) that can be readily obtained. Because of the uncertainty in the current design, the model has the versatility to vary the amount and order of the various unibed media.

The type of the media remains constant, but the model has the capability to allow the user to eliminate one or more of the media. If a media is not completely removed, it is assumed that it was not decreased to the point that the length/diameter ratio was insufficient to provide adequate contaminant removal.

A table defined the nominal contaminant concentrations for the various individual waste streams. The table was used to help gain an understanding of the type of contaminants the model would consider, with the understanding that the model has

the capability to accept varying concentrations of these and other contaminants. Another table defined the baselined composition of the single loop unibed.

Due to the complexity of the task, the following information was included:

- a) Identify the model constraints
- b) Estimate model accuracy
- c) Describe technical background of how the model was developed
- d) Identify testing support required to support model development (rapid small scale column data)

Additional information in the proposal included ION/MSFC support in terms of providing ECLS waste waters and unibed media for testing. An agreement was reached between ION/NASA MSFC/ED62 and NASA Ames Research Center whereby any data generated by their contract with MTU on unibed modeling was available for this effort. Therefore, experimental data charged to this contract did not include applicable data generated/charged through the Ames contract.

The proposal included a phase development schedule. This schedule included milestone costs and duration. Phase I required that the feasibility of the effort, resulting in the desired end product be proven before the contract was continued and future funding provided. The remainder of the effort, Phase II, was broken into distinct milestones to allow progress reviews.

MTU submitted technical and financial data listed:

Monthly Progress Reports and/or Milestone Reports
Monthly Contractor Financial Management Reports (Form 533M)
Final Report*, Final Program User's Guide and Computer Model
(* = pending as of August 1995)

3.1.9 Special Test Hardware Procurement/Fabrication

ION procured and fabricated special test hardware items required for subsystem and system level tests. Emphasis was placed on quick turnaround. Typical items that were required included valves, fitting, temperature and pressure sensors, flowmeters, pumps, fans, tanks, and accumulators, heaters, chillers, heat exchangers, plumbing lines, equipment racks, electrical connectors, power supplies, expendable chemicals and reagents, sample containers, filters, adsorption units, bottled gases, ersatz or synthetic waste water, and computer supplies.

3.1.10 VCD Flight Assessment, Task J-3, and VCD Flight Experiment, Task J-9, NAS8-38250-11

TASK A: Vapor Compression Distillation (VCD) Flight Assessment

ION investigated the feasibility of flying a Vapor Compression Distillation (VCD) urine processor flight experiment. A plan was developed which assessed modifications to existing VCD Life Test subsystems required to meet manned flight requirements, and

assessed potential flight vehicles (Spacelab, Spacehab, etc.) relative to available utilities and flight opportunities. The plan also included a recommended flight experiment configuration, cost and schedule information, trades and analyses results, and a development plan.

ION furnished materials, supplies, personnel, facilities, equipment and management to carry out the work.

ION and LSI investigated and defined the modifications necessary to the Life Test Unit (VCD-VA), previously fabricated and delivered, to upgrade it into a Flight Experiment Unit applicable for flight demonstration on board vehicles such as the Spacehab or Spacelab. Special emphasis was placed on maximizing use of the existing hardware/designs. Where existing hardware/designs could not be retained, modified, upgraded or replacement of Flight Unit hardware items were recommended to meet the unique specifications and requirements of on-orbit flight experiments. The output of this effort was a flight experiment definition of a VCD-based Waste Water Processor equivalent in content to efforts typically resulting from Phase A and Phase B flight experiment definitions.

ION established the objectives, requirements, and specifications for a VCD-based Waste Water Processor flight experiment for on-orbit flight demonstration within a Spacehab, Spacelab or MIR environment, or combination thereof.

ION defined the level of detail and developed a full-size mock-up of the proposed VCD flight experiment. Incorporated the capability to demonstrate the hardware use, in the Spacehab, Spacelab or MIR environment, or combination thereof.

ION prepared the necessary program documentation and program management and control.

LSI submitted technical and financial data listed:

- Monthly Progress Reports and/or Milestone Reports
- Monthly Contractor Financial Management Reports (Form 533M)
- Conceptual Design Review and Documentation

Task B: VCD Urine Processor Flight Experiment

ION/LSI took an existing conceptual design for a Vapor Compression Distillation (VCD) urine processor flight experiment and developed a preliminary design. Resource requirements were finalized, all interfaces defined, form/fit/function assembly drawings completed, and a preliminary design review conducted.

Beginning with a conceptual design derived in a previous effort (Task A), completed the preliminary design of the experiment/mission scenario, including operational constraints, operating modes, experimentation, and protocol.

Finalized resource requirements and interface definition, including upgrading mechanical schematics, and electrical interconnecting block and wiring diagrams.

Completed form, fit, and function assembly drawings of mechanical components of the embedded controller, including subassembly/component/parts drawings as appropriate.

- Distillation Unit
- Fluids Control Assembly
- Pressure Control Assembly
- Fluids Pump Assembly
- Purge Pump Assembly
- Recycle Filter Tank Assembly
- Wastewater Storage Tank Assembly
- Pretreatment Storage Tank Assembly
- Control and Monitor Instrumentation

ION/LSI defined experiment hardware packaging arrangements and maintenance (scheduled and unscheduled, if applicable) concepts and procedures.

Upgraded requirements and defined ground support equipment design and requirements.

Upgraded product assurance effort through preliminary design.

- Safety, Reliability, and Quality Assurance Plan
- Safety Hazard Analysis
- Failure Modes and Effects Analysis (FMEA)
- Critical Items List
- Nonmetallic and Metallic Materials Lists
- Safety Compliance Data Package

Upgraded and/or prepared program and preliminary design documentation.

- Monthly financial and technical reports
- Upgrade end-item specification
- Preliminary Design Review (PDR) meeting agenda
- PDR Document
- Interface Control Document (ICD)
- PDR meeting minutes
- Review Item Discrepancy (RID) closure reports

Prepared for, conducted, and followed up on the required meetings including travel.

- Safety review
- PDR Meeting
- RID close-out meeting

Completed the required program management activities.

- Internal program management
- External program management

Deliverables were documentation listed in the preceding paragraphs including the Preliminary Design for the VCD flight experiment.

Task C Continued Urine Ersatz Development

This task continued the evaluation of pretreated urine ersatz formulations for the Vapor Compression Distillation (VCD) Urine Processor Assembly (UPA). The ersatz evaluation began with the data obtained from a development phase completed under Task B. The ersatz was formulated to imitate the physical properties of urine pretreated with oxone and sulfuric acid yet chemically and biologically stable over a broad range of environmental conditions. Pre-concentrated urine was also evaluated as an ersatz formulation.

Following the approved prescribed plan, identified candidate formulations and procured materials for test evaluation.

In addition to pre-concentrated urine, other ersatz formulations were investigated. One candidate formulation for bench scale testing was selected.

The merits of a solids-loading test of the refill filter tank filter which demonstrated filter oversize, were evaluated.

Performed bench scale characterization testing of the selected formulation. Used vacuum distillation to obtain concentrated solutions to evaluate concentrated brine solution fluid properties.

Characterized the formulation for the properties at the initial concentration.

Characterized the formulation for the following specifications at 25°C. Specifications are listed in order of importance.

Conductivity	ohms	constituents must dissociate to some extent into charged particles
Vapor Pressure	mm Hg	20 (±5)
Surface Tension	dynes/cm	40(±8)
Solubility	g ppt/L	increase with solids concentration
Viscosity	centistokes	increase with solids concentration
*Temperature extremes will occur during ascent, descent, and shipment. Temperature low 5°C, high 40°C.		

Evaluate, and document in a test log, the candidate formulation performance in the VCD-VI test unit at LSI using the following protocol:

- Thoroughly flush the unit with distilled water prior to test.
- Prepare the formulation and run through the full solids concentration of a batch.
- Disassemble the Distillation Assembly and inspect for the presence of precipitated solids and reassemble.
- Thoroughly flush the unit with distilled water to return unit to pretest condition.

Selection Report: Data were submitted for review. Specification comparisons of pre-concentrated urine and each alternate ersatz was documented. One (1) candidate formulation was identified within six weeks of contract start date. Acceptance of the one candidate formulation was granted before continuation. For traceability, all information pertaining to chemicals, vendors, batch number, and any other information was submitted. Described all formula benefits and limitations pertaining to the VCD WWP flight experiment.

Characterization Report: Bench test data used to evaluate concentrated brine solution fluid properties were submitted and discussed. Initial formula characterizations were submitted and discussed. Ersatz formulation characterization was documented and discussed.

Evaluation Report: Evaluations of the preferred formulation performance in the VCD-VI test unit at LSI were documented and discussed. Original test logs were submitted as appendices.

Final Report: Prepared/submitted the test program DRAFT final report with recommendations for use of the preferred formulation in the VCD WWP flight experiment. After receipt of comments/edits, prepared and submitted the final report.

3.1.11 Mostly Liquid Separator Development, Task H-6 and Process Pump Development, Task J-1, NAS8-38250-12

Task A Development and Life Test of the Water Processor Process Pump

The SOW addressed activities to perform life testing on the process pump design for use in the Space Station (SS) Water Recovery and Management (WRM) System. The process pump is located in the Waste Water Orbital Replaceable Unit (ORU) of the Water Processor (WP) and provides the pumping power necessary to flow the waste water through the WP for processing. The design requirements necessitated a pump life of 10 years on SS. Previous testing of pre-development water recovery systems showed that to achieve this pump life was a significant design challenge.

The SOW was divided into three major tasks. Task I required the use of previous test data and analysis to upgrade two existing flight design process pumps. Task II was an accelerated life test of the two pumps using actual waste water under WP operating conditions. Task III required the contractor to write a final report summarizing the results and conclusions from Tasks I and II.

Task 1 - Upgrade Existing Flight Design Process Pumps - The contractor reviewed existing test and analysis data and evaluated the present process pump design and determined what modifications to make to improve the pump's performance and life. Once the next generation pump design had been developed, Hamilton Standard upgraded two existing process pumps to meet the new process pump design. The next generation process pump design was submitted to ION Electronics for information before the existing pumps were modified.

Task 2 - Perform Life testing on upgraded Process Pumps - HS developed a test plan to evaluate the life and performance of the redesigned process pump in the operational environment expected in the WP. This plan was submitted to ION Electronics for approval before preceding with the test. The test requirements included, but were not be limited to, performance maps of each pump prior to and at the end of the test period, the use of real waste water (including shower waste water), the evaluation of on/off cycling effects on pump life and performance, and an anomaly review team which included NASA/MSFC and ION representatives. During the testing period weekly telecons occurred to inform ION of test status.

HS submitted a final report which documented and summarized the results of the contract work, including recommendations and conclusions based on the experience and results obtained as stated.

Task B: Development and Test of the Water Processor Mostly Liquid Separator

The SOW addressed activities to develop and test an engineering prototype Mostly Liquid Separator (MLS) design for use in the Space Station (SS) Water Recovery and Management (WRM) System. The MLS is located in the Waste Water Orbital Replaceable Unit (ORU) of the Water Processor (WP) and provides for the removal of free gas in the waste water to prevent WP performance degradation due to gas build-up in the system.

The SOW was divided into three major tasks. Task I required the use of previous test data and analysis to design and build two MLSs. Task II was parametric testing of the two MLSs using actual waste water under WP operating conditions. Task III required HS to write a final report summarizing the results and conclusions from Tasks I and II.

Development of and Engineering Prototype MLS Design: HS reviewed existing test and analysis data as well as performed analysis necessary to develop an engineering prototype MLS design. The operating requirements for the MLS were as follows:

Inlet Free Gas Content:	0% to 100% min/max 0% to 14% average
Inlet Water Flow Rate:	0-900 PPH from Waste Bus plus 57 to 63 PPH from Recirculation Pump
Inlet Temperature:	65 °F to 113 °F
Inlet Pressure:	0 - 8 psig
Inlet Water Quality:	SSF Waste Water as defined by the "Potable Water Processor Assembly Envelope Drawing", Boeing Document number 683-10019.
Carryover:	0.4% gas in water outlet 0% water in gas outlet

Once the MLS had been developed, HS fabricated two MLS prototypes (one plastic (lexan), one of appropriate material to be determined). The MLS prototype design was submitted to ION for information prior to fabrication. Each unit was fabricated from materials which facilitated the evaluation of the MLS design and performance.

Parametric Testing of the Two MLS: HS developed a test plan to evaluate the performance of the MLS design in the operational environment expected in the WP. The plan was submitted to ION for approval before preceding with the test. The test requirements include, but were not limited to: 1) Performance maps of each MLS prior to, and at the end of, the test period; 2) The use of real waste water (including shower waste water); and 3) the evaluation of the MLS performance with regard to varying inlet free gas content, inlet water flow rates, inlet water temperatures, inlet pressures, and inlet cleansing agent concentrations. During the testing period weekly telecons occurred to inform ION on the test status.

Final Results Summary Report: HS wrote a final report which described the work performed and listed all data collected. The report discussed the development of the prototype MLS. The report included development drawings generated. The report gave an evaluation of the test data collected and provided conclusions and recommendations for any further design changes necessary to meet the present WP performance requirements.

HS submitted a final report which documented and summarized the results of the contract work, including recommendations and conclusions, based on the experience and results obtained.

3.1.12 PCWQM Development, Task H, NAS8-38250-13

ION procured a development unit Process Control Water Quality Monitor (PCWQM) which was utilized in the Predevelopment Operational System Test (POST) Water Reclamation test. A pilot model PCWQM was upgraded to development unit status and shipped to ION Electronics for use in the POST Test.

The water processor design for the SSF WRM Subsystem employs a Process Control Water Quality Monitor (PCWQM) to verify acceptability of water prior to use. The development of this monitor is scheduled to culminate with a Critical Design Review (CDR) in November of 1994. However, a flight like PCWQM has never been integrated with the Hamilton Standard Water Processor and had its performance verified in a systems level test. An integrated test involving a flight like PCWQM is necessary to verify that the design of the PCWQM can be integrated with the Water Processor. The first scheduled systems level integrated test involving a flight like PCWQM is the Baseline Operations System Test (BOST). The current schedule for the delivery of a flight like PCWQM for integrated systems testing shows that the BOST PCWQM would be delivered at the same time as the flight units, creating a near impossible task of modifying the flight design based on the performance of the PCWQM in an integrated test. However, a PCWQM could be manufactured and delivered for testing in the Predevelopment Operations System Test (POST). Though performance data would not be available for the PCWQM CDR, design inconsistencies

brought to light during POST could be corrected in the flight hardware prior to manufacturing.

The Pilot Bench PCWQM was refurbished with the necessary flight like sensors and components so that it was successfully integrated and operated in POST. Any additional expendables required to complete POST testing were provided.

The Pilot Bench PCWQM was also repackaged in a manner that allowed it to be transported and operated without hazard to personnel or equipment. Astro International, Inc. prepared an operations manual and provided onsite instruction needed to successfully integrate and operate the hardware. Integration included software interfaces for process control and data acquisition. Interfaces for the PCWQM were defined in the POST Test Plan, Boeing Document #D683-10326-2.

The refurbished Pilot Bench PCWQM underwent verification testing prior to shipment.

Astro International, Inc. delivered one Pilot Bench PCWQM that utilized the sensor technology proposed for the flight design of the PCWQM. This hardware was capable of being integrated into the POST test with the Water Processor and operated throughout the POST test. Astro provided the operations manual Pilot Bench PCWQM and arranged for qualified personnel to be available at MSFC for ten days for integrating the PCWQM hardware and for instructing POST technicians in the operation of the PCWQM.

3.1.13 Spacelab Charcoal Analyses, Phase II, Task D-1, NAS8-38250-14

The Statement of Work (SOW) addressed activities to analyze charcoal samples taken from NASA Spacelab's Trace Contaminant Removal System (TCRS). Battelle Memorial Institute (BMI) analyzed the samples by methodologies proposed. Each sample was designated by the sample location and type.

Polar compound analyses was performed on four (4) Spacelab mission's charcoals, IML, USML-1, SLJ, SLD2, and SLS2. The IML and SLJ charcoal samples were in the custody of Dr. Slivon/BMI. These two sample sets were analyzed for polar compounds. The additional spacelab sample sets, USML-1, SLD2, and SLS2 were analyzed for polar and non-polar compounds. A table represented compounds detected in previous analyses. The USML, SLD2, and SLS2 sample sets were comprised of seven (7) samples each.

BMI analyzed IML, USML-1, SLJ, SLD2, and SLS2 simultaneously once all samples were received. In addition, USML-1, SLD2 and SLS2 sample sets were immediately shipped to BMI for analyses.

BMI provided a final narrative report after all analyses had been completed. The report included: an introduction; technical approach; results; and discussion sections. In addition, tables, graphs, and chromatographs were included in the final report.

3.1.14 TCCS Catalyst Bench Test, Task J-12, NAS8-382500-15

Task A: Trace Contaminant Oxidation Catalyst Poisoning Investigation

Development testing of the Trace Contaminant Control Subassembly (TCCS) which removed and oxidized atmospheric trace contaminants from the space station cabin atmosphere showed that catalytic oxidation performance of the 0.5% Pd/Al₂O₃ catalyst for certain contaminants decreased over time as the subassembly's charcoal bed became saturated. The primary contaminant showing this performance loss was methane. Per pass oxidation efficiency fell from nearly 100% to 5%¹ over a period of 35 days. Corresponding to this per pass efficiency decrease, the dichloromethane concentration entering the catalytic oxidizer assembly increased from zero to 10 ppm. Both the methane oxidation efficiency and the dichloromethane concentration stabilized at their final values at test day 35. Following the 45-day test, the charcoal bed was repacked with fresh charcoal and the methane oxidation performance recovered over a period of 10 days to almost 90% per pass. Efficiency recovered to 90% per pass after 7 days at the normal oxidizer operating temperature. Oxidizer temperature was increased 100 °F to 850 °F during the last 3 days. The temperature increase resulted in the additional 5% per pass efficiency gain.

This result is similar to tests conducted by the European Space Agency (ESA) on a 0.4% Pd/Al₂O₃ in the presence of methane and bromotrifluoromethane (Halon 1301). In these tests, the Halon 1301 concentration was increased stepwise to as high as 583 ppm. Oxidation efficiency of the 300 ppm methane inlet decreased stepwise from over 98% to 10%. Unlike the TCCS development test, the catalytic oxidation performance recovered within 24 hours. These results were duplicated in system-level tests conducted later.

Both catalyst poisoning tests did not investigate the performance effects which may result from repeated poisoning/recovery cycles. The current approach to maintaining high catalytic oxidizer performance is to replace the oxidizer after six months of operation. This approach is not logistically efficient and results in high life cycle costs for the TCCS. Given the test results, it is highly likely that a single catalyst charge may have a much longer useful life.

The key is to determine the number of poisoning/recovery cycles which can be experienced before the oxidation performance is no longer capable of maintaining the cabin concentrations of methane below its Spacecraft Maximum Allowable Concentration (SMAC).

The objective for this task was to determine the number of poisoning/recovery cycles which can be tolerated by the TCCS catalyst charge before the average oxidation efficiency fell below 10% per pass. This information was useful for determining the logistics requirements for the TCCS during its useful life onboard the space station.

¹ Per Pass Oxidation Efficiency =
[(% Methane in - % Methane out) / % Methane in] X 100

Investigation of the poisoning characteristics was subdivided into the following subtasks:

A baseline performance test using 100 ppm methane at a 750 °F catalyst temperature and 8,000 h⁻¹ space velocity² was conducted. This test determined the normal methane oxidation performance before introducing poisons.

A baseline performance test using 10 ppm dichloromethane concentration to determine the catalytic oxidation performance with respect to the individual poisoning compound was conducted. Temperature and flow conditions are those of Subtask 1. Oxidation products were monitored and quantified. Attention was given to the possible production of carbonyl chloride in addition to hydrogen chloride.

A baseline performance test using 0.5-1.0 ppm of hydrogen sulfide or carbonyl sulfide was conducted. Temperature and flow conditions are those of Subtask 1.

A stepwise poisoning test using dichloromethane concentrations ranging from 0 to 25 ppm increasing in at least 5 ppm increments and methane at 100 ppm was conducted. The catalyst flow and temperature conditions of Subtask 1 apply. Steady state was achieved before increasing or decreasing the dichloromethane concentration. The stepwise test also included a final segment where the dichloromethane concentration was reduced from the highest concentration to zero and the recovery of methane oxidation performance observed. This test provided information on the effects of varying poison concentration on the methane oxidation performance.

A stepwise poisoning test using hydrogen sulfide or carbonyl sulfide to determine the sensitivity, if any, of methane oxidation performance to varying sulfur compound concentrations was conducted. Poison concentration varied between 0 and 2.0 ppm and increased at 0.5 ppm increments followed by a post test recovery period. 100 ppm methane along with the temperature and flow conditions of Subtask 1 were used.

A cyclic poisoning test using dichloromethane ramped from 0 to 10 ppm over a 24 hour period was conducted. Oxidation performance of 100 ppm methane was monitored over time until steady state is reached. Upon reaching steady state, the dichloromethane injection was stopped and the catalyst allowed to recover. Methane oxidation efficiency was monitored until no additional improvement was obtained. Dichloromethane introduction using the ramped introduction concentration to 10 ppm was repeated and the cycle monitored as before. This test continued for 20 cycles or until methane oxidation performance did not recover to above 10% per pass. Temperature and flow conditions are those of Subtask 1.

A cyclic poisoning test using 100 ppm methane and a ramped concentration of 0 to 0.5 ppm hydrogen sulfide or carbonyl sulfide was conducted only if the stepwise poisoning test indicated that recovery from sulfur compound poisoning was reversible at the temperature and flow conditions of Subtask 1.

A cyclic poisoning test using 100 ppm methane and a ramped concentration of 0 to 0.5 ppm hydrogen sulfide or carbonyl sulfide and 0 to 10 ppm dichloromethane was

² Space Velocity = (Volumetric Flow Rate / Total Free Volume of Packed Column)

conducted only if the cyclic poisoning test with hydrogen sulfide or carbonyl sulfide indicated that poisoning was reversible at the temperature and flow conditions of Subtask 1.

All tests conducted began with a fresh catalyst charge which has had a baseline performance determined for it for 100 ppm methane in air at $8,000 \text{ h}^{-1}$ space velocity and 750°F reactor temperature.

Monthly reports were provided no later than the 15th day of the following month. Five copies were submitted and the contents included:

- Brief statement of the work accomplished during the monthly reporting period
- Description of the work performed and the overall project status
- Pertinent sketches and drawings
- Test results
- Discussion of problems or potential problems

A final report was provided within one month of the end of the contract period of performance. The report contained detailed information for the following:

- Background material
- Project objectives
- Experimental apparatus used
- Experimental methods used
- Task and subtask descriptions
- Experimental results in tabular and graphic form
- Discussion of results
- Conclusions

ION provided 10 kg of 0.5% Pd/Al₂O₃ catalyst pellets manufactured by Engelhard Corp. from Lot no. 35850. Initially, 5 kg was provided and an additional 5 kg was provided as necessary.

3.1.15 VRA Procurement, Task H-4, NAS8-38250-16

Task A: Procurement of Volatile Removal Assembly (VRA) Reactor

ION procured a baselined SSF Potable Water Processor catalytic oxidation reactor utilize in government performance testing. Items procured included one catalytic reactor and approximately 250 cc of raw catalyst material. The reactor included an oxygen sparger that is the current flight design. The reactor was utilized for in-house testing that provided empirical data used to develop a mathematical model of the catalytic oxidation reactor with testing planned to begin during fiscal year 1994.

Hamilton Standard (HS) constructed one VRA reactor and oxygen sparger used for developing a mathematical model of the VRA reactor performance. The reactor was equipped with temperature and pressure sensors for monitoring reactor performance. The reactor and sparger were checked out prior to shipment to verify nominal performance. Hamilton Standard manufactured 250 cc of their proprietary catalyst.

HS provided one VRA reactor containing their proprietary catalyst on alumina substrate. The reactor was equipped with the oxygen sparger used to impart oxygen into the process stream.

HS provided the documentation necessary to properly operate the reactor.

HS provided 250 cc of raw catalyst used in small column experiments. Agreements were reached with the contractors which involved ensuring that their experimental efforts were in no way be used to determine the proprietary nature of the catalyst.

3.1.16 Molecular Sieve Bench Test and Computer Modeling, Task J-5, NAS8-38250-17

Task A: Molecular Sieve/Bench Testing and Computer Modeling

ION Electronics requested specialized engineering services from McDonnell Douglas to complete development of a phenomenological 4BMS computer model. Molecular sieve material adsorption dynamics bench testing was completed to obtain the remaining data required. The bench test was operational in Building 4755. The adsorption data from this test was used as input to an existing computer model with the output being an updated model (delivered to ION) which accurately predicts molecular sieve performance.

The scope of this effort completed development of an analytical model of the Four-Bed Molecular Sieve which was capable of predicting performance when the operating conditions and/or the hardware configuration were changed. The approach accurately modeled the adsorption and desorption processes in the molecular sieve material. Dynamic testing of a subscale adsorption column to obtain breakthrough data was conducted on NASA provided equipment as required for development and verification of the computer model. A literature search was conducted to obtain fundamental sorbent characteristics.

Adsorption dynamics testing to obtain LDF mass transfer terms and model verification data.

Adsorption Dynamics testing (underway in Building 4755) was completed as required for development and verification of the computer model on existing NASA provided equipment. Data from this testing was used to derive Linear Driving Force mass transfer coefficients. This test also provided temperature and mass concentration profiles for a packed bed, which was used for verification of the computer model. Phases of testing included:

Sufficient testing was completed to provide model development/verification data on three sorbent materials: silica gel; zeolite 5A; and zeolite 13X. Single component adsorption of water on silica gel, and of water and CO₂ on zeolites 5A and 13X were tested. For each gaseous component, two different inlet concentration levels were tested. Multi-component testing for the zeolites 5A and 13X were performed with water and carbon dioxide. Four tests for each sorbent were run such that each component is varied independently.

Strip desorption of the sorbents silica gel and zeolite 13X were performed following saturation from each of the adsorption test conditions above.

For the sorbent zeolite 5A, thermal-vacuum testing was required following bed saturation resulting from the single component CO₂ adsorption and multi-component CO₂/H₂O adsorption tests.

For the zeolite 5A material, a multi-cycle test was required which consists of multiple adsorption/desorption cycles. The test mimicked CDRA operational parameters and continue until duplicating cycles were achieved.

A literature search was performed for fundamental sorbent characteristics as required for development and verification of the computer model and to determine the availability of required data. All data obtained through this search and the literature sources was documented in the final report. Characteristic data included equilibrium isotherms for each sorbent material (silica gel, molecular sieves 5A and 13X) and principle sorbates (CO₂ and H₂O). Other data including but not limited to density, packing density, thermal conductivity, surface area, porosity, heat of adsorption, and equivalent spherical diameter were obtained from the open literature as required for completion of a verified model. If reliable data was not available in the open literature, the lacking required data was identified in documentation as a candidate requirement of future adsorbent characteristic testing.

Development of a phenomenological computer model of the Four-Bed Molecular Sieve (4BMS) was completed. The program may operate independently or within the CASE/A program. This model is capable of accurately predicting, at a minimum, CO₂ removal performance, and power requirements when operating conditions (including but not limited to cycle time, inlet temperatures and dewpoints, process flow rate, and heater control algorithm) or hardware configuration (including but not limited to bed size and sorbent packing configuration) are changed. The modeled components include:

The desiccant bed model has the capability to represent three layers of sorbent material. The thickness and type of sorbent material is selectable from the choices of silica gel and zeolite 13X. Flow-through adsorption and desorption were modeled.

The CO₂ sorbent bed model models an electrically heated canister with zeolite 5A sorbent material. Flow-through adsorption as well as thermal and pressure swing desorption were modeled. Models of (a) a vacuum pump and (b) a vacuum reservoir, with the effects of the appropriate tubing from the canister modeled, are included. The vacuum options are selectable for adjustable time periods and sequence during the desorption half-cycle.

Ancillary components include the 4BMS precooler, blower, and valves. These components were integrated with the sorbent beds to allow modeling of the entire 4BMS. The existing CASE/A program component routines may be used for this purpose as long as they are validated prior to integration with the overall model.

Verification of the computer model consisted of a comparison of the model output data with actual test data. The tests used for comparison included the Molecular Sieve Material Bench Test (MSMBT) data as well as a fully integrated 4BMS test. Comparisons were made with both open loop and closed loop operations. Data used for comparison included, although is not limited to, CO₂ and H₂O partial pressure, temperature, flowrate, and total pressure at the inlet and outlet of each sorbent bed; temperature, flowrate, and total pressure at the inlet and outlet of the blower, precooler, and vacuum pump, and at the inlet of the vacuum reservoir; and CO₂ and H₂O partial pressure, temperature, flowrate, and total pressure at the 4BMS system inlet and outlet.

A user's guide to the model was prepared. The guide enables a new user who is familiar with the 4BMS design and the adsorption process (and CASE/A if the program is utilized) to operate the model without further assistance. A listing of the code and a description of the major arrays and variables included.

A final report was submitted in narrative form which documents and summarizes the results of the computer model development and experimental work conducted. At a minimum, general headings of Introduction, Theoretical Model, Experiment Description and Results, Numerical Approach, Computer Model Verification, Summary and Conclusions are included.

The source code for the computer model was delivered to a MSFC computer. All code required for actual running of the model and interpretation of model data were supplied.

Two copies of the model documentation were supplied. One copy was in reproducible form.

Two copies of the final report were supplied. One copy was in reproducible form.

The SOW required a 10 month performance period.

3.1.17 VRA Computer Modeling, Task H-4, NAS8-38250-18

Task A: Developing an Analytical Model of the SSF Water Processor Catalytic Oxidation Reactor

The water processor design for the SSF Water Recovery and Management (WRM) Subsystem employs two techniques for removing contaminants from the waste water. First, waste water is treated via multifiltration technology, which utilizes a series of ion exchange resins and carbonaceous or polymeric adsorbents packaged to optimally remove ionic compounds and some organics. Catalytic oxidation technology is utilized to further purify the waste water by removing low molecular weight, polar organics. These contaminants are not well removed by the multifiltration technology and thus prevent the potable water quality specification for Total Organic Carbon (500 ppb) from being met. The importance of the catalytic oxidation process in meeting the SSF potable water quality requirements leads to the necessity of predicting its performance based on varying contaminant loads. The modeling effort would

culminate in the delivery of a computer program capable of simulating the performance of the catalytic oxidation reactor and a final report detailing the effort. The following defines the scope of the task.

The final model is capable of defining the performance of the catalytic oxidation process in terms of contaminants removal efficiency with varying input conditions. These input conditions include varying the contaminant load and the duration of this load in terms of process water throughput, reactor residence time (i.e., catalyst volume), pressure, and temperature. The model is applicable for, but not limited to, a process stream flow rate of 15 lbs/hr to which oxygen is added for the oxidation reaction at a rate of 0 to 0.009 lbs/hr. As a design option the model is capable of predicting reactor performance for a process stream saturated with oxygen at the influent temperature and pressure (current flight design pressure range is 64-83 psig). The model is also able to predict the lowest oxygen concentration required in the influent water to provide sufficient oxidation in the reactor to meet the potable water specification of 500 ppb TOC in the product water.

The model is able to estimate the reactors capability to remove a contaminant based upon a set of specified contaminant properties (e.g., molecular weight, solubility, etc..) that can be readily obtained.

3.1.18 Laboratory and Test Subject Support, Task L, NAS8-38250-19

Development of the Environmental Control and Life Support System (ECLSS) for the International Space Station (ISS) is the responsibility of the Marshall Space Flight Center (MSFC). To fulfill this responsibility, ION contracted with Boeing to conduct a variety of development tests in the Core Module Integration Facility (CMIF) located in building 4755 at MSFC. These tests address various technical issues related to regenerative water recovery and air revitalization functions. The tasks cited in this Statement of Work (SOW) were completed through a subcontract under ION prime contract number NAS8-38250.

Water recovery provides purification of various wastewaters for reuse by the crew. The major assemblies involved with water recovery include those for urine processing, water processing, water quality monitoring, and the various tankage and plumbing components which are needed to integrate them together. Emphasis at MSFC is placed on conducting testing of development-maturity assemblies integrated together to function as a complete water recovery and management subsystem. To ensure that the test conditions employed are of the highest possible fidelity, human test subject volunteers were utilized to generate the various wastewaters processed during integrated water recovery and management testing.

Air revitalization provides control of atmospheric major and trace gas constituents within safe limits. The major assemblies involved with air revitalization include those for carbon dioxide removal, oxygen generation, trace contaminant control, and atmospheric composition monitoring. Emphasis at MSFC is placed on conducting testing of development-maturity assemblies for oxygen generation, carbon dioxide

removal, and major constituent monitoring integrated together in a closed door chamber to test control of the major atmosphere parameters.

In addition to the testing of integrated water recovery and air revitalization assemblies, life testing of selected stand-alone assemblies is being conducted. This life testing is dedicated to the evaluation of the long-term performance of critical processing components. Assemblies that are currently undergoing life testing include a Four-Bed Molecular Sieve (4BMS) carbon dioxide removal assembly, a Trace Contaminant Control Subassembly (TCCS), and two Vapor Compression Distillation (VCD) urine processing assemblies. Life testing of Microbial Check Valve (MCV) components is also planned. Where necessary, specialized bench tests are conducted to obtain data necessary to enhance the understanding of the phenomenological processes occurring within various ECLSS components. One such component to be evaluated in bench tests was the Volatile Removal Assembly (VRA) catalytic reactor.

In each of the types of testing described above, important performance data was provided by collecting appropriate water and air samples from the hardware being tested and subjecting those samples to accepted analytical laboratory procedures to determine their physical, chemical, and/or microbiological constituency.

This SOW defines tasks conducted in support of integrated water recovery testing, integrated air revitalization testing, life testing, and special tests conducted in MSFC's building 4755 from April 1994 through February 1995. Specifically, ION/Boeing provided analytical support services necessary to obtain validated physical, chemical, and microbiological data on selected water, surface, and air samples, provided a pool of medically certified test subject volunteers, and provided updated test descriptions/information and analytical results for the Freedom Environmental Database System (FEDS).

ION/Boeing conducted physical, chemical, and microbiological analyses on water samples collected from integrated water recovery tests. These analyses were performed using previously approved ACC or EPA/Standard methods. Final determination and prioritization of sample schedules were mutually agreed to by ION and Boeing as test plans were finalized.

ION/Boeing conduct physical and chemical analyses on air samples collected from integrated air revitalization tests. These analyses were performed using previously approved ACC or EPA/Standard methods. Final determination and prioritization of sample schedules were mutually agreed to by ION and Boeing as test plans were finalized.

ION/Boeing conducted physical, chemical, and microbiological analyses on water and air samples collected from ECLSS life tests. These analyses were performed using previously approved ACC or EPA/Standard methods. The types of analyses required, and the estimated frequencies, were listed. Final determination and prioritization of sample schedules were mutually agreed to by ION and Boeing as test plans were finalized.

ION/Boeing conducted physical, chemical, and microbiological analyses on water samples collected from special tests. The special tests included but were not limited to equipment and animal ersatz development, Trace Contaminant Removal System (TCRS) charcoal analyses, Total Organic Carbon Accountability (TOCA), Water Degradation Test analyses, and Volatile Removal Assembly (VRA) Bench Test analyses. These analyses were performed using previously approved ACC or EPA/Standard methods. TOCA analyses and ersatz development were documented through narrative reports. The reports, at a minimum, described methods and procedures utilized, analytical results interpretation/discussion, and figures to include graphs, charts, and chromatographs. The types of analyses required, and the estimated frequencies, were listed. Final determination and prioritization of sample schedules were mutually agreed to by ION and Boeing as test plans were finalized.

All data supplied in fulfillment of Tasks A through D was generated in accordance with the requirements defined in MSFC's *Analytical Control Test Plan and Microbiological Methods for Water Recovery Testing, (Version 3.1)*. Automated transmittal of all validated data was provided by Boeing for MSFC's Freedom Environmental Database System (FEDS) as a comma delimited ASCII file. Fast-turnaround data was provided by Boeing via facsimile or equivalent method as needed to support real-time operations.

ION made appropriate updates to the FED's tables to incorporate new tests, stages, days, batches, groups/subgroups, port numbers, lab IDs, and subsystem descriptions. This activity was orchestrated through BCSS and the Test Data Custodian.

ION provided qualified individuals to collect water and air samples from sample locations designated by MSFC. ION provide all necessary materials to support the collection of these samples and to insure their integrity. Boeing provided means to transport the samples to the laboratory.

ION made available a pool of test subject volunteers to participate in ECLSS testing. Test subject involvement included activities necessary to generate representative wastewater for subsequent processing by water recovery equipment. Test subject involvement was limited to donor mode only. Test subject involvement and safeguards were in accordance with the approved Protocol for the Participation of Human Research Subjects in the *Environmental Control and Life Support System Phase III Test Program: Water Recovery Test Stages 4, 5, and 7* (commonly referred to as Protocol B) or subsequent protocol approved by the MSFC Institutional Review Board (IRB). ION provided all necessary medical screening and monitoring of test subjects to meet protocol requirements. Twenty-four test subjects were required per day prior to and during the test. A pool of 80 test subjects were required.

3.1.19 Microbial Surface Growth, Task G-3, NAS8-38250-20

Microorganisms, in addition to potentially causing opportunistic infections, may cause the biodeterioration of surfaces. The need to incorporate anti-microbial compounds into fabrics, rubbers, plastics, and other components of Space Station (SS) was investigated to prevent or reduce the amount of microbially induced damage to surfaces. In addition, selected materials that have exposure to the SS artificial

environment were tested in similar conditions to estimate the degree of the potential problem(s) and to establish, if necessary, a maintenance schedule.

Altran performed a literature search on the influence of microorganisms on the SS selected materials. Factors like air contaminants, surface microbial populations, and water adsorption properties that can influence materials degradation were investigated. The major task was the effect on exposed surfaces (like walls) and non-exposed surfaces (like circuit boards). An assessment of the factors that can affect the microbial induced degradation in zero-G was also investigated. This included data from previous missions as well as information on the materials and kinds of degradation observed by the Russians during their SS occupancy.

The data collected was reported in a tabular format which can be easily adaptable to an electronic database (i.e., as a tab delimited ASCII file).

Altran provided information on the microbial composition of the close habitat like SS. The major task was to perform a literature search to find information about the microbial composition of the air and surfaces in similar closed environments. An assessment of the factors that affect the microbial population in zero-G was also investigated. Altran provided data from previous missions as well as from the air and surface microbial population recovered by the Russians during their SS occupancy.

The data collected was reported in a tabular format which can be easily adaptable to an electronic database (i.e., as a tab delimited ASCII file).

Experimental protocols were developed using the results of the literature search and the experience gained by the Russians from the operation of the SS MIR. These protocols were consider the current temperature and humidity levels baselined for the International Space Station Alpha (ISSA).

The contractor submitted monthly technical reports detailing work performed during the month. The reports were submitted no later than 10 days after the month being reported.

3.1.20 SFE IV-A Refurbishment, Task H-9, and WRT/ART Support, Task J-10, NAS8-38250-21

Task A: Refurbishment Of The SFE-IVA Statement Of Work

This Statement of Work (SOW) addresses activities necessary to refurbish the Pre-development Operational System test (POST) Static Feed Electrolyzer (SFE-IVA) for use in the Integrated Air Revitalization Test. The SFE technology has been proposed as the Oxygen Generation Assembly (OGA) on the International Space Station (ISS).

Previous SFE-IVA and Comparative Test Unit (SFE-IV) testing revealed several SFE design problems that require modifications to both hardware and software before qualification for flight. ISS requirement changes will demand additional modifications.

The major task modified the SFE-IVA hardware and software in preparation for the Integrated Air Revitalization Test. This task was divided into the following subtasks.

Based on previous experience with the SFE-IVA and on initial inspection and checkout of the unit, LSI analyzed hardware problems, modified hardware to correct those problems, and verified by test the effectiveness of the modifications. Problems addressed included, but are not limited to, the following:

Cell flooding due to overfeeding - Added electrolyte to the circulating water loop simplified unit cyclic operation.

Aerosol causing buildup on the pressure control assembly poppets - An aerosol filter cells to both product gas streams was added.

Excessive thermal swings - The addition of an external heat exchanger to the Thermal Control Assembly (TCA) controlled thermal swings.

Short life of the TCA pump gears and bushings - Changed to a non-gear pump.

LSI analyzed the potential impacts to the SFE-IVA hardware and software of the new ISS requirements affecting OGA operation. LSI implemented the necessary modifications to make the SFE-IVA compatible with those requirements and verified the modifications by test. The following requirements were considered:

OGA operation on the daylight side of the orbit only - This requirement demanded frequent and rapid system startup and shutdown.

100 psia nitrogen interface - The available nitrogen pressure is lower than the optimum system pressure. Software and hardware modifications were required.

Oxygen generation rate control - Software and hardware modifications necessary to allow the O₂ generation rate to be varied was implemented. As a minimum the capability to generate O₂ at a nominal rate of 7.4 lbm/day and at rates equal to nominal +/- 10 % was provided.

Upon completion of the necessary hardware and software modifications, LSI performed a checkout test of the integrated SFE-IVA system.

Following successful completion of the checkout test, LSI packaged the SFE-IVA and ship it to ION Electronics (ION) where it was checked and forwarded to Marshall Space Flight Center (MSFC) and subsequently integrated into the Integrated Air Revitalization Test in building 4755. LSI charged the system with electrolyte and verified proper installation of the system in the testbed. LSI provided support, as required, during the SFE-IVA checkout test, including leak checks, and during the Integrated Air Revitalization test.

LSI provided a final report, detailing the SFE-IVA modifications and all testing results, and a Familiarization and Operation Manual for the system.

Task B: Subcontractor Support For Integrated Atmosphere Revitalization Test
Statement Of Work

This Statement of Work (SOW) addresses the support required from subsystem vendors prior to and during the Integrated Atmosphere Revitalization Test. This work is exclusive of any planned work to refurbish or modify hardware prior to the test, which is described under separate SOWs

Provide Technical Support for Subsystem

Each hardware vendor provided a technical point of contact for their subsystem to support the following activities as needed from the test team:

- Subsystem installation and integration
- Test software and controls development
- Subsystem checkout testing
- Integrated system testing

40 hours of support was allocated on an on-call basis and was provided from the time contract start through one month after the integrated test was complete.

The vendor provided technical assistance as needed to support any troubleshooting and anomaly resolution activities required for their subsystem. On-site support at MSFC was required depending on the severity of the anomaly and the required fix for up to 40 hours.

Task C: Technical Support For The Water Recovery Test Stage 9

The Environmental Control and Life Support (ECLS) test program at the Marshall Space Flight Center (MSFC) was divided into phases beginning with the stand-alone ECLS subsystem bench tests (Phase I) in August, 1986. The Phase II program, which concluded in November of 1987, provided the first experience with an ECLS system that included four air revitalization and one urine processor assemblies operating in integrated fashion for periods of up to six days. The present Phase III program has expanded on the Phase II integrated test experiences by including the recovery of potable and hygiene water with man-in-the-loop. The Phase III Water Recovery Test (WRT) to date has evaluated the performance of a "dual-loop" water recovery system comprised of separate potable and hygiene water recovery subsystems operating in open-loop "donor" mode (Stages 1A, 2A, and 3A) and closed-loop "recipient mode" (Stages 4 and 5). The WRT has also evaluated a "single-loop" water recovery system with on subsystem processing both hygiene and potable water waste streams in "donor" and "recipient" modes (Stages 7A and 7B) and without a pre-sterilizer (Stage 8). A third "single-loop" test (Stage 9) is scheduled to be performed in 1994. This test evaluated the latest water recovery system design for the United States On-Orbit Segment (USOS) of the International Space Station Alpha (ISSA) with higher fidelity hardware and integration than has been achieved in previous WRT Stages.

This Statement of Work (SOW) addresses the support required from the WRM subsystem contractor prior to and during the Phase III WRT Stage 9.

The subsystem contractors were required to support subsystem installation and integration and software development activities prior to the Stage 9 test, provided on-call support during testing, and assisted in the on-site troubleshooting of anomalies.

The contractor provided a technical point-of-contact for their subsystem to support the following activities as needed:

- Subsystem installation and integration (PCWQM excluded)
- Test software and controls modification and development
- Subsystem checkout testing
- Integrated system testing

The contractors supported troubleshooting and anomaly resolution activities as required for their subsystems. 80 hours of on-site support was allocated.

3.1.21 LFSPE Refurbishment, Task H-11, And WRT/ART Support, Task J-10, NAS8-38250-23

Task A: Refurbishment Of The LFSPE Statement Of Work

This Statement of Work (SOW) addresses the activities necessary to refurbish a Liquid Feed Solid Polymer Electrolyzer (LFSPE) Technology Demonstration Oxygen Generator for use in an oxygen generator comparative test.

Modifications were made to correct problems encountered during earlier testing, and to address recent requirements changes.

The major task was to refurbish and modify the LFSPE hardware and software in preparation for comparative testing. This work was divided into the following subtasks.

Based on previous experience with the LFSPE and on initial inspection and checkout of the unit, Hamilton Standard analyzed hardware problems, modified hardware to correct those problems, and verified by test the effectiveness of the modifications. Problems addressed included, but were not limited to, the following:

- Water carryover in hydrogen phase separator
- Blistering of hydrophobic material under operating conditions
- Inadequate heat rejection
- Failures in oxygen and hydrogen outlet valves

Hamilton Standard analyzed the potential impacts to the LFSPE hardware and software of the new International Space Station (ISS) requirements affecting Oxygen Generator Assembly (OGA) operation. Hamilton Standard implemented necessary modifications to make the LFSPE compatible with those requirements and verified the modifications by test. The following requirements were be considered:

- OGA operation on the daylight side of the orbit only - This requirement demanded frequent and rapid system startup and shutdown.

100 psia nitrogen interface - The available nitrogen pressure is lower than the optimum system pressure. Pressurization control software required modification. Hardware modifications were also required.

Oxygen generation rate control - Software and hardware modifications, if any, necessary to allow the O₂ generation rate to be varied were implemented. As a minimum the capability to generate O₂ at a nominal rate of 7.4 lbm/day and at rates equal to nominal +/- 10% was provided.

Upon completion of the necessary hardware and software modifications, Hamilton Standard performed a checkout test of the integrated LFSPE system.

Following successful completion of the checkout test, Hamilton Standard packaged the LFSPE and shipped it to ION Electronics (ION) where it was checked and forwarded to MSFC and subsequently integrated into the Oxygen Generator Comparative Test in building 4755. Hamilton Standard charged the system with electrolyte and verify proper installation of the system in the testbed. Hamilton Standard provided support, as required, during the LFSPE checkout test, including leak checks, and during the Oxygen Generator Comparative Test.

Hamilton Standard provided a final report, detailing the LFSPE modifications and all testing results, and a Familiarization and Operation Manual for the system.

Task B: Technical Support For The Water Recovery Test Stage 9 Statement Of Work

The Environmental Control and Life Support (ECLS) test program at the Marshall Space Flight Center (MSFC) was divided into phases beginning with the stand-alone ECLS subsystem bench tests (Phase I) in August, 1986. The Phase II program, which concluded in November of 1987, provided the first experience with an ECLS system that included four air revitalization and one urine processor assemblies operating in integrated fashion for periods of up to six days. The present Phase III program has expanded on the Phase II integrated test experiences by including the recovery of potable and hygiene water with man-in-the-loop. The Phase III Water Recovery Test (WRT) to date has evaluated the performance of a "dual-loop" water recovery system comprised of separate potable and hygiene water recovery subsystems operating in open-loop "donor" mode (Stages 1A, 2A, and 3A) and closed-loop "recipient mode" (Stages 4 and 5). The WRT has also evaluated a "single-loop" water recovery system with on subsystem processing both hygiene and potable water waste streams in "donor" and "recipient" modes (Stages 7A and 7B) and without a pre-sterilizer (Stage 8). A third "single-loop" test (Stage 9) is scheduled to be performed in 1994. This test evaluated the latest water recovery system design for the United States On-Orbit Segment (USOS) of the International Space Station Alpha (ISSA) with higher fidelity hardware and integration than has been achieved in previous WRT Stages.

This Statement of Work (SOW) addresses the support required from the WRM subsystem contractor prior to and during the Phase III WRT Stage 9.

The subsystem contractors were required to support subsystem installation and integration and software development activities prior to the Stage 9 test, provided on-call support during testing, and assisted in the on-site troubleshooting of anomalies.

The contractor provided a technical point-of-contact for their subsystem to support the following activities as needed:

- Subsystem installation and integration (PCWQM excluded)
- Test software and controls modification and development
- Subsystem checkout testing
- Integrated system testing

The contractors supported troubleshooting and anomaly resolution activities as required for their subsystems. 80 hours of on-site support was allocated.

3.1.22 4BMS Blower Procurement, Task H-12, and ART Support Task J-10, NAS8-38250-24

The task provided for the fabrication of a Carbon Dioxide Removal Assembly (CDRA) mixed flow blower assembly according to Allied-Signal Aerospace Company release drawings and the delivery of the blower to ION Electronics (ION) for subsequent use in the ECLSS Life Testing Program (ELTP). Also included are provisions for blower performance and interface data which allowed proper integration of the blower assembly into the current CDRA ELTP test article.

The ELTP began in November 1992 as a program to investigate the life-related characteristics of selected ECLSS atmospheric revitalization and water recovery hardware. As part of the initial phase of the ELTP, a prototype CDRA has been under test to investigate the useful life cycle of the desiccant and adsorbent bed materials under space station environmental conditions. The ELTP requirements provide for the expansion of the ELTP to include flight-maturity hardware as it becomes available. Several high priority components have been identified for the expanded ELTP including the CDRA blower assembly. The blower assembly is high priority because it is a central component to not only the CDRA but also the Trace Contaminant Control Subassembly. By testing a single blower assembly, information can be gathered on life-related issues such as mechanical bearing wear, motor life, and impeller vane life. The blower will be integrated into the ELTP CDRA test article and operated continuously under simulated space station conditions with the exception of the microgravity environment.

The objective was to fabricate and take delivery of a flight maturity CDRA blower assembly and integrate it into the ELTP CDRA test article in Building 4755 at MSFC.

AlliedSignal provided a flight maturity CDRA blower assembly as described in Allied-Signal Aerospace Company release drawing 2353165. The blower assembly included the motor controller and all mechanical and electrical interfaces necessary to operate the blower as part of the ELTP CDRA test article. Also, AlliedSignal provided blower performance curves and the latest revision of the release drawings which were used for integrating the blower assembly into the CDRA test article. Documentation of

a preliminary acceptance test for the assembled blower was provided. Final acceptance testing was conducted at MSFC upon delivery. Technical support from Allied-Signal Aerospace Company was also provided as necessary.

Deliverable items for this task were the following:

- One flight maturity CDRA blower assembly fabricated according to drawing 2353165
- One CDRA blower assembly controller
- Mechanical and electrical interface documentation
- Blower performance curves (total head vs. speed and volumetric flow rate)
- Preliminary acceptance test results documentation
- 80 Hours technical support

3.1.23 POST 4BMS Modifications, Task H-13, NAS8-38250-25

The Statement of Work (SOW) addressed the activities necessary to modify the Pre-development Operational System Test (POST) Four Bed Molecular Sieve (4BMS) to reflect current flight configuration. Changes have occurred during the latest reconfiguration, which now include additional crew members for the Russian Space Agency, and while there is still valuable knowledge to be applied from testing while in the earlier configuration, these latest changes need to be reflected in all future testing.

The major task was to modify the CDRA (4BMS) to reflect current flight configuration.

POST 4BMS unit was modified to operate in a cyclical manner. Heaters were only operational during the day side of orbit. The 4BMS was configured to respond to a signal from a central controller designating which cycle (day or night) to use. Current day side/night side timing was 56/36 minutes respectively. The unit is able to respond to other cycle times and also retain the capability to run continuously.

The impact of the new U.S. LAB segment specification for CO₂ removal performance was assessed by AlliedSignal. Changes to the current configuration (hardware, software) of the flight CDRA design to meet the new specification were reported to ION for consideration. ION and AlliedSignal decided as a team which changes to implement in the POST CDRA. AlliedSignal documented all changes to POST hardware decided upon by the test conduct team.

After the modifications of hardware, software, and operational procedures mentioned had been made, AlliedSignal conducted a complete system checkout and verification of nominal operations of the modified POST 4BMS.

AlliedSignal provide a final report, detailing the CDRA (4BMS) modifications and all testing results, and a Familiarization and Operation Manual for the system.

3.1.24 MCA Checkout and Repair, Task H-14, and ART Support, Task J-10, NAS8-38250-26

Task A: Repair/Refurbishment Of Pre-Dev MCA

The Statement of Work (SOW) addressed the activities necessary to troubleshoot and repair the pre-development Major Constituent Analyzer (MCA) problems that were encountered near the end of the Atmosphere Control & Supply (ACS) Predevelopment Operational System Test (POST). The repairs were made before the proposed Integrated Air Revitalization (AR) Test scheduled February 15, 1995.

The problems encountered in the pre-dev MCA, suggest cause(s) for them, and proposes what the possible solution(s) might be along with instructions for periodic refurbishment currently needed. The pre-dev MCA was thoroughly inspected to verify the accuracy of the problems stated in this SOW. The plausibility of the repairs suggested were determined if any repairs beyond those suggested were needed.

The purge flowrate for the Stand-Alone MCA dropped out of nominal range at the end of the ACS POST. A blockage in the sample line or malfunction in SAS SV5 is believed to be the problem. Verify power needed to actuate the valve is applied when appropriated command is given. If it is revealed that electrical power is not reaching the valve, then contractor personnel performed diagnostics and troubleshooting on the electrical system.

Changed rough pump oil per MGA 1200 Operations and Maintenance Manual.

Verified nominal operation of the Stand-Alone MCA. If any anomalies are noted, obtain contractor assistance to identify and document the problem and determine the appropriate corrective action.

Upon completion of the necessary hardware, OSC performed a checkout test of the Pre-DEV MCA.

Checkout and repair of the MCA was performed at MSFC's building 4755. OSC verified proper installation of the system. OSC provided support, as required, during the checkout test.

OSC provided a final report, detailing the MCA modifications and all testing results. An Operation Manual for the system was modified to reflect the changes.

3.1.25 Unibed Model Development - Phase II, Task J-6, NAS8-38250-27

TASK A: The continuing development and verification of the space station multifiltration unibed model statement of work

The water processor design for the Space Station (SS) water recovery and Management (WRM) Subsystem employs multifiltration technology for the removal of contaminants from Environmental Control and Life Support (ECLS) waste waters.

Multifiltration technology utilizes a series of ion exchange resins and carbonaceous adsorbents packaged into a unibed in an order designed to achieve optimal contaminant removal. The importance of the unibed in the design of the WRM leads to the necessity to predict its performance and life.

To accomplish this goal without requiring costly performance testing, an effort to develop an analytical model of the unibed performance was initiated by Michigan Technological University (MTU) under contract to McDonnell Douglas Space Systems Company (Contract SK90A049). This initial effort performed by MTU involved modeling the performance of the potable loop humidity condensate unibed. The humidity condensate unibed model was limited in its application, though it proved useful in defining the steps necessary to develop a unibed model for a single loop water processor. Based on this effort's conclusions and the modification of the Space Station WRM to a single loop water processor, MTU was funded by ION Electronics (Contract #NAS8-38250-10) to begin development of a single loop water processor multifiltration unibed model.

This effort was segmented into two phases. During Phase I, the model was developed solely for a waste shower/handwash waste water. This approach was used to simplify the effort by avoiding the complexity associated with modeling the treatment of all ECLS waste waters. The Phase II effort was expanded to include all waste waters. Due to funding and time constraints, the Phase I effort was partially completed with FY93 funds. The results of the effort completed are described in the draft report submitted to ION Electronics by MTU entitled *Development and Verification of the Space Station Freedom Multifiltration Model*, February, 1994.

In summary, this effort addressed the performance of the ion exchange resins, including equilibrium and kinetic studies. Additional work to be performed to complete the Phase I effort is the kinetic and equilibrium studies for the unibed's adsorption media and the development of the modeling software.

This Statement of Work defines tasks conducted that culminated in the delivery of a computer program capable of simulating the performance of the SS single loop unibed for processing waste shower/handwash water. MTU performed testing and analysis of the various aspects of the unibed performance and used the data to develop mathematical equations capable of predicting how the unibed's performance and life are affected by various influent contaminant loads. This effort was a continuation of previous work conducted by MTU on the unibed model.

The ion exchange model was completed and the modeling of the unibed's adsorption process was fully developed by the end of the contract period. Prior to delivery the model's capabilities were verified by comparing actual test data to model predictions.

MTU developed, validated, and delivered a computer-based analytical model with the following capabilities:

The model is capable of defining unibed performance in terms of contaminant removal efficiency and life expectancy with varying input conditions defined by the model user. These input conditions include varying the composition of the waste

shower/handwash water. The model is capable of accepting user-defined changes to: 1) the ratio of the individual waste streams combined into the single waste stream entering the unibed; 2) the concentrations of individual contaminant species concentrations within each waste stream; and 3) the time period for which the waste water is processed. The throughput for each waste water constituency is definable by the end user.

Though the contaminants expected to be present in the waste water are defined, the model is able to estimate the unibed's capability to remove a contaminant based upon a set of specified contaminant properties (e.g., molecular weight, solubility, etc.) that can be readily obtained. Because of the uncertainty in the current unibed design, the model has the capability to allow the user to vary the amount and order of the various unibed media. The type of the media remains constant. If a media is not completely removed, it is assumed that it is not decreased to the point that the length/diameter ratio is insufficient to provide adequate contaminant removal.

Phase II task included performing isotherms of the single loop waste water. This water was generated at the conclusions of the Stage 9 Water Recovery Test to take advantage of this ongoing effort. MTU provided the isotherm bottles and media, as well as the instructions needed to successfully carry out the experiments. The physical and chemical isotherm analysis was conducted by Boeing Analytical Laboratory under contract to ION.

MTU identified the model constraints and provided a detailed description of the technical development of the model. Additional information included required ION/MSFC support in terms of providing ECLS waste waters and unibed media for testing. An agreement was reached between NASA MSFC and NASA Ames Research Center whereby any data generated by the contract with MTU on unibed modeling was available of this effort.

A table defined the nominal contaminant concentrations for the various individual waste streams comprising the single loop waste water. The table was used to help gain an understanding of the type of contaminants the model considers, with the understanding that the model has the capability to accept varying concentrations of these and other contaminants. Table 2 defined the baseline composition of the single loop unibed.

The contractor delivered the following to ION.

- Bimonthly Progress Reports and Milestone Reports
- Monthly Contractor Financial Management Reports (Form 533M)
- Final Report
- Final Program User's Guide and Computer Model

3.1.26 Urine Pretreatment Development, Task J-7, NAS8-38250-28

Task A: Various urine pretreatment injection methods statement of work

Hamilton Standard evaluated various urine pretreatment methods for the Space Station (SS) Waste Management System through a trade study and testing. Selected pretreatment injection methods were designed and manufactured to a prototype configuration. Each of the prototype configurations were tested using the functional Extended Duration Orbiter (EDO) as a baseline. Test results and design data were evaluated and recommendations made relative to the best pretreatment method.

Hamilton Standard performed the following tasks to define the optimum method for introducing chemicals into a urine stream in the SS urine collection system.

Conducted a trade study to determine which urine pretreatment injection method(s) were manufactured and tested. The criteria used for decision-making included, but not be limited to the following:

- Simplicity of design
- Crew handling and safety
- Envelope and weight requirements
- Material compatibility
- Commonalty between space station and shuttle hardware

Refurbished the existing EDO urinal for use in testing the pretreatment hardware identified in Task I.

Fabricated test set-up for testing the pretreatment prototype(s).

Manufacture/fabricate the pretreatment prototypes.

Test prototype dispenser(s) and record data which includes:

- Mechanical performance of dispenser
- Amount of fouling noted on separator
- Efficiency of prototype dispensing method in adequately pretreating urine
- Typical pressure and flow-rate data expected from fluid dynamic testing

Defined hardware packaging arrangement and maintenance (scheduled and unscheduled, if applicable) concepts and procedures.

Prepared program documentation.

- Monthly financial and technical reports
- Final Report including recommendation for optimum method
- All drawings that are developed for this project.

Deliverables were prototype urine pretreatment hardware which can be further tested or used in a future flight experiment to uncover any micro-gravity characteristics of the system.

3.1.27 SFE Flight Experiment Through PDR, Task J-8, NAS8-38250-29

Task A: SFE Flight Experiment Statement Of Work

LSI developed a preliminary design for a Static Feed Electrolyzer (SFE) flight experiment. Maximum use was made of existing designs available from an engineering development unit used to support the Space Station (SS) program. Resource requirements were finalized, interfaces defined, form/fit/function assembly drawings were completed, and a preliminary design review was conducted.

Defined an SFE flight experiment configuration capable of flight demonstration on board either the Spacelab or Spacehab spacecraft.

LSI conducted trade studies and analysis and define flight experiment configuration including necessary design/product assurance documentation and conducted an Initial Design Review. Documentation prepared under this task included:

- Design Configuration Document
- Preliminary Technical Requirements Document
- Preliminary Interface Control Document
- Mechanical Schematic with Sensors
- Preliminary Safety Hazards Analysis

LSI prepared the preliminary design for the flight experiment including necessary design/product assurance documentation. Conducted a Preliminary Design Review (PDR). Documentation prepared under this task included the following:

- Reliability and Quality Assurance Plan
- Preliminary Failure Modes and Effects Analysis
- Preliminary Critical Items List
- Preliminary Metallic/Nonmetallic Materials List
- Form, fit and function assembly drawings of all components.

LSI define the level of detail and develop a full-size mockup of the flight experiment. Incorporated the capability to demonstrate the hardware use in either the Spacelab or SPACEHAB.

LSI provided program management and control.

An Initial Design Review occurred in November 1994 and the Preliminary Design Review in March 1995.

Deliverables included all documentation and drawings, both technical and programmatic, as well as the full-size mockup. LSI prepared the necessary programmatic documentation including:

Nine (9) monthly technical & financial progress reports.
Preliminary Design Program Final Report & Discrepancy (RIP).

**3.1.28 Polymerase Chain Reaction Assessment, Task J-13,
NAS8-38250-2695**

Task A: Development Of A Microbial Water Quality Monitor

Future manned spacecraft development for long duration missions will require water reclamation to avoid excessive launch weights or frequent re-supply of water. It is important to monitor the waste water recovery systems to detect a process failure and prevent contamination of potable and hygiene water supplies. This Statement of Work (SOW) addresses activities needed to further develop available Polymerase Chain Reaction (PCR) technology for microbial water monitoring. The end product will be a pre-prototype of a microbial monitor that could be adapted to the Space Station water system. This SOW addresses the Phase I effort which demonstrated the feasibility of PCR technology.

Ensuring the microbiological quality of potable and manufacturing waters, to protect public health, requires the detection of indicator organisms as defined by the U.S. Environmental Protection Agency (EPA). The traditional methods for detecting bacteria rely upon culturing bacteria on agar media (conventional number). The use of these methods, for the detection and identification of microorganisms, is generally a time consuming and tedious process, not suited to applications where information may be needed within hours.

The Space Station (SS) is an example of a water processing system where rapid detection of low levels of pathogenic microorganisms is of utmost importance. Monitoring the microbial populations and identifying changes in relative populations might indicate that a steady-state balance is not being maintained and may serve as an early warning that the Environmental Control and Life Support System (ECLSS) is not performing properly and needs to be checked. The microbial population of reclaimed water during SS hardware development testing is <10 CFU/100 mL. The water samples' microbial diversity during testing has been found to have a maximum of 20 different genera. The amount and bacterial diversity of microorganisms can fluctuate depending on system performance. Future government development objectives are to quantify the total viable microbial population and to detect and identify viable pathogenic microorganisms in the processed water on a real time basis.

Current approved microbial monitoring techniques do not meet all space application requirements. The development of a technology for a real-time microbial monitor, with application for industry (such as food processing, pharmaceutical, etc.) and adaptable to use within spacecraft restrictions, allows the consumption of recycled water shortly after processing. This reduces the requirement for prolonged water storage prior to use, therefore, reducing the amount of storage tanks needed.

The water microbial population probably exhibits changes throughout the life of the SS. Therefore, flexibility in system design is important to allow for technological upgrades. During the microbial monitor design stages, UAB developed a protocol so a prototype monitor can be tested during SS's hardware design stages.

All work performed was correlated (if applicable) to a standard method "control" for reference. UAB was required to provide facilities, equipment, supplies, reagents, expendables as needed, and their Standard Operating Procedures (SOP).

This task addressed the feasibility of using PCR or related technology to quantify viable total counts in water samples. The limitations, including detection limits, sensitivity, time of detection, and complexity of the technology, were described. This effort was performed through literature searches, technology searches, or similar means.

UAB submitted monthly technical reports. The reports were submitted no later than 10 days after the month being reported.

Teleconferences were held as required for technical clarification and direction.

UAB submitted five copies of the final report detailing the SOW. The report gave an evaluation of all data collected, conclusions, and recommendations for any additional work.

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